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SYSTEMATIC VARIATIONS IN INSHORE BATHYMETRY

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13. ABSTRACT

In order to investigate systematic geographic variations in subaqueous beach-zone morphology, we analyzed profiles taken from the shoreline to 1200 feet (365 m) offshore along the United States Atlantic and Gulf coasts for characteristic forms using an eigenvector analysis. The first three eigenfunctions derived accounted for more than 97% of the topographic variance in the profile data. The first eigenfunction represents slope departure from the mean; the second and third functions are related to variations in bar/trough morphology. Because of the orthogonality of the various eigenfunctions, we were able to conclude that there is no relationship between profile slope and presence or absence or number of bars on the profile. Because the significance of the three eigenfunctions varied systematically along the Atlantic and Gulf coast, we were able to classify various coastal reaches according to profile forms. Partial direct and inverse correlations were also found between the inshore slope (0 to 1200 feet [0 to 365 m]) and offshore slope (1200 feet to 9 miles [365 m to 14 km]).

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SYSTEMATIC VARIATIONS IN INSHORE BATHYMETRY

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TABLE OF CONTENTS

LIST OF FIGURES

FIGURE | | PAGE

LIST OF TABLES

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ABSTRACT

In order to investigate systematic geographic variations in subaqueous beach-zone morphology, we analyzed profiles taken from the shoreline to 1200 feet (365 m) offshore along the United States Atlantic and Gulf coasts for characteristic forms using an eigenvector analysis. The first three eigenfunctions derived account for more than 97% of the topographic variance in the profile data. The first eigenfunction represents slope departures from the mean; the second and third functions are related to variations in bar/trough morphology. Because of the orthogonality of the various eigenfunctions we were able to conclude that there is no relationship between profile slope and presence or absence or number of bars on the profile. Because the significance of the three eigenfunctions varied systematically along the Atlantic and Gulf coasts, we were able to classify various coastal reaches according to profile forms. Partial direct and inverse correlations were also found between the inshore slope (0 to 1200 feet [0 to 365 m]) and offshore slope (1200 feet to 9 miles [365 m to 14 km]).

INTRODUCTION

In Technical Report No. 5, *Classification of Coastal Environments: Analysis Across the Barrier Island Interfaces* (Resio et al. 1973), the organization of the coastal environment normal to the trend of the coast was investigated through the definition of six zones characterizing sets of process-form interactions (Fig. 1). Through Q-mode principal component analysis, the characteristic arrangements of the width of these zones were analyzed. Eight types of barrier-island interface environments were isolated and only a coarse scale organization (100's of miles) along the coast was detected. In Technical Report No. 5 we said that further stratification of the environmental organization normal to the coast would require additional analyses of the variability within each of the six zones defined. To accomplish this stratification, our University of Virginia research team designed a program for these analyses; this report deals with the analysis of the subaqueous (or inshore) beach-zone morphology.

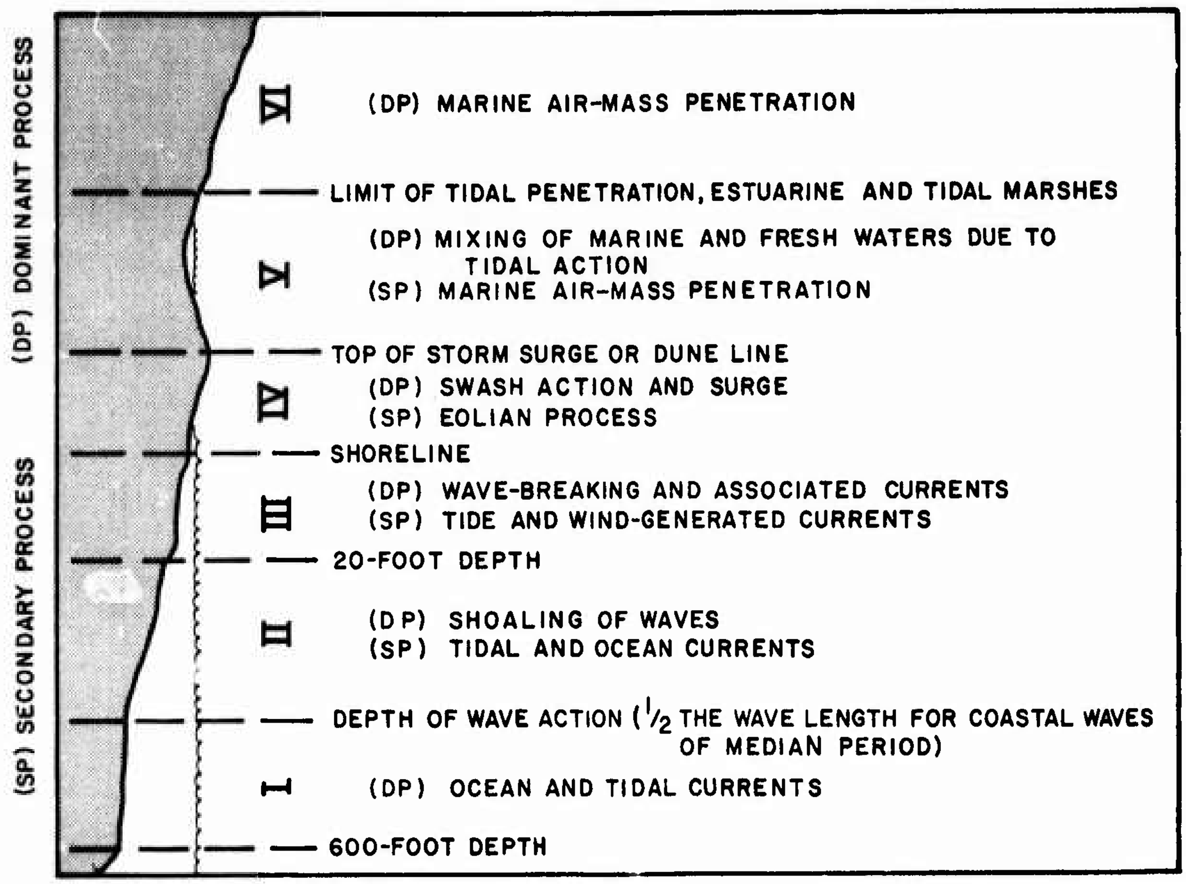
Dolan et al. (1973) defined the subaqueous beach zone as that area between MLW and the 20-foot (6 m) depth contour. We have used Dolan's MLW as the landward limit; however we were unable to use the 20-foot (6 m) depth contour as the seaward limit because of the lack of detailed bathymetric data. A 1,200-foot (365 m) distance criterion was used instead because a complete data set could be amassed from MLW to 1,200 feet (365 m) offshore. Along the east coast of the United States, the 20-foot (6 m) depth contour and the 1,200 foot (365 m) offshore criterion are approximately the same; along the Gulf coast the 20-foot (6 m) depth contour is significantly seaward of the 1,200-foot (365 m) offshore distance.

Previous Research

Previous studies of bottom geometry in the nearshore area have dealt with local topographic maxima, variously termed "bars" (Bascom 1964; Bird 1969), "low and ball" (Evans 1940), "ridge and runnel" (King and Williams 1949; King 1959) or "swash bar" (King 1959) depending on the author and the degree to which the feature was exposed to subaerial processes. Johnson (1919) and Zenkovich (1967) in their reviews of the early work in the subaqueous zone mentioned the remarkable persistence of offshore bars in certain areas, the relationship of these bars to the offshore slope, the effect of severe storms on the bar system, and the role of breaking waves in shaping this zone. In 1919 Johnson ended his review by admitting that very little was actually known about the geomorphology of the subaqueous beach zone. Extensive wave-tank experiments and observations before, during, and just after World War II showed that the bar system was the major feature of the inshore zone. Correlations have been established between the depth of water over the bar crest and the incident wave height (Evans 1940; Keulegan 1948; Shepard 1950; Shepard 1952; McKee and Sterrett 1961) and between the slope and bar occurrence (Zenkovich 1967; Lau and Travis 1973). In 1962, Zenkovich first reported that bars were the major channel for longshore sediment transport and that the formation of bars was restricted to a fairly narrow range of slopes (0.02-0.005) and grain sizes (0.1-0.5 mm). In 1959, King suggested that the separation between "ridge-and-runnel" forms

FIGURE 1

Process Zones Parallel to the Coast (Dolan et al. 1973)



was generated by swash processes (Fig. 1, Zone IV), and that "breakpoint" bars were associated with breaking waves. In 1952, Shepard reviewed the terminology and suggested different terms for barrier islands, baymouth bars, and longshore bars.

More recently, study of the inshore zone has been concentrated on the hydrodynamics of bar formation and the three-dimensional variations in inshore form. Davis and Fox (1972) suggested a model for bar formation and migration based on wave/current interaction, and Lau and Travis (1973) found that "the number of bars is likely to increase when the bottom gradient is 'slight'". In 1973, Sonu presented an excellent review and discussion of the latest progress in this area.

Previous research has largely focused upon the temporal variations in morphology. In this study we have investigated systematic geographic variations in subaqueous beach-zone morphology. Our analyses were designed to answer specific questions: 1) In what characteristic and independent ways do inshore profile forms vary? 2) Are these variations systematically organized along extensive reaches of the coast? 3) Do the separate forms of profile variation codominate a given coastal location or are they geographically isolated?

Since bathymetric data in two-dimensional or profile form provide multiple variables of depth along a transect, we used multivariate statistical methods for the analysis of profile data collected along the Atlantic and Gulf coasts of the United States.

DATA ACQUISITION AND REDUCTION

Inshore bathymetric data, available in several forms (hydrographic charts, boat sheets, fathometer traces, and reduced or plotted profiles), vary in accuracy, sampling density, and date of data acquisition. We assessed the data form for its applicability to a systematic study of subaqueous beach-zone morphology. Hydrographic charts and boat sheets are unsuitable because their integrated form filters out significant local variations. Although fathometer traces provide adequate data and are available for selected areas, they were used only as a back-up source because of the length of time involved in extracting data in digital form. Ultimately, reduced, or plotted, profiles in varying graphic forms provided the best combination of accuracy and ease of data recovery in digital form. The various sources we used are listed here in order of our preference:

(1) Digital data on IBM cards (one case only);

(2) U.S. Corps of Engineers blueline cross-section sheets: 1" = 200" horizontal scale, 1" = 5' vertical scale;

(3) Manuscript profiles on cross-section paper 1" = 100' horizontal scale, 1" = 5' verticale scale;

(4) Photographic reproductions of (2) at 1" = 250' horizontal scale 1" - 7' vertical scale;

(5) Various published profiles, usually reduced copies of (2) at 1" = 800' horizontal scale, 1" = 20' vertical scale.

We recorded depth values from graphic data at 50-foot (15 m) intervals beginning at MLW. For those profiles for which no MLW line was shown, such as chart data, first MSL and/or then MHW were preferred as the zero point. For manuscript and published data, we recorded the depth values by hand and then keypunched them onto data cards. Photocopied and blueline data were reduced on a Calmagraphic II digitizing machine which produced punched-paper tape output. We then reformatted images of the paper tape to conform to the material manually keypunched.

This process resulted in a catalogued set of over 2,000 profiles in the original graphic format. From these profiles we selected the set of 504 digital-format profiles which we used for most of the analyses in this study and which we refer to as the basic data set.

The distribution in time and space of the available graphic data is highly variable, resulting in a heavy sampling of some areas and in a light sampling of others (Fig. 2). Data-through-time at some profile sites is available for only one year and at others for as many as nine years. When data covering different years at different sites was available, the years of sampling did not necessarily coincide. Therefore, although the raw data set is essentially random in time (from year to year), the basic data set is restricted to the most recent available data at each site.

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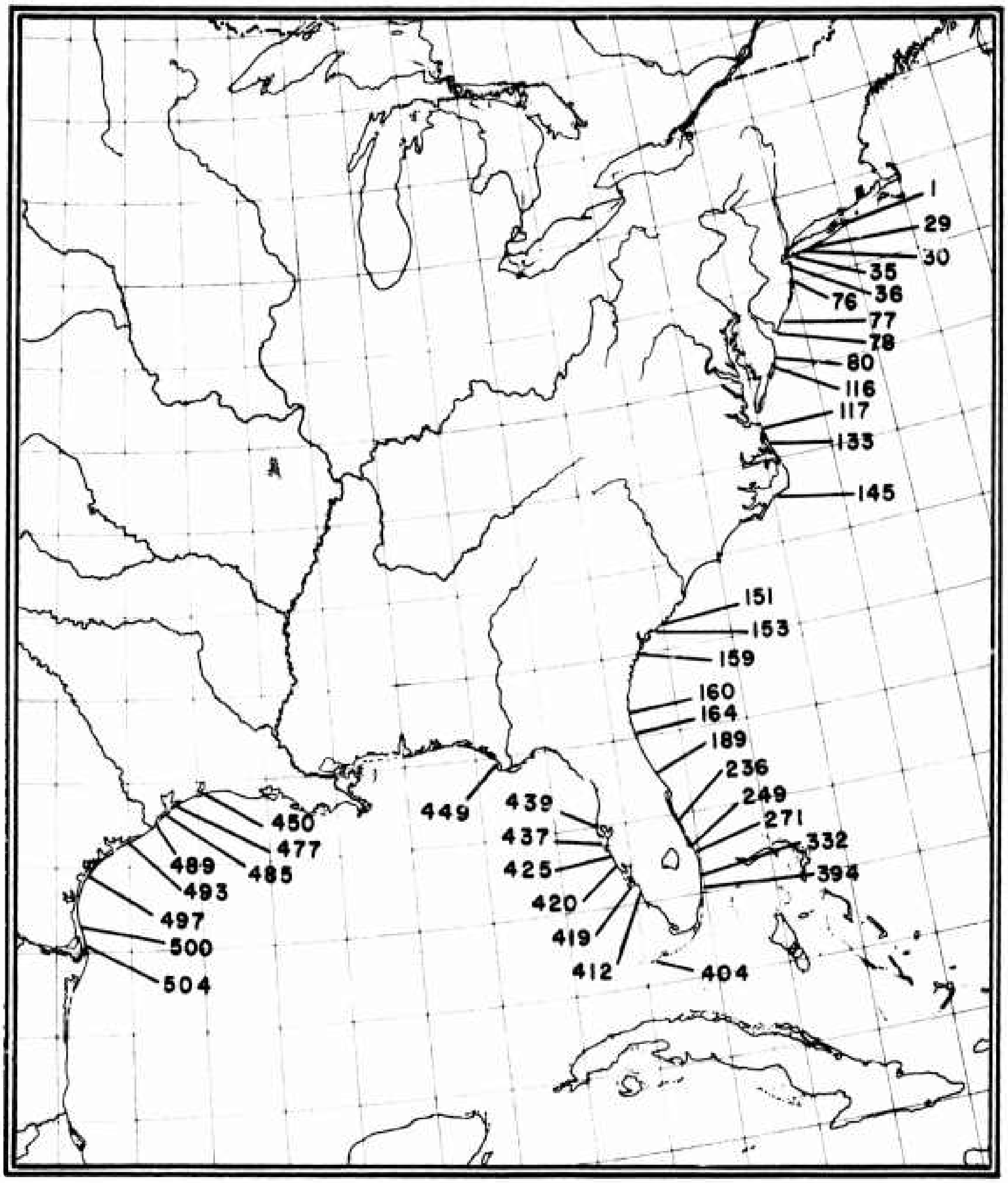
FIGURE 2

Location Map of the 504 Profiles in the Basic Data Set



ANALYSES

We designed the analyses of the assembled basic data set to isolate and to characterize two basic attributes of the subaqueous beach-zone morphology: overall form of the profile and elements of local relief. No assumptions about process-response relationships were made in the multivariate statistical analyses used to analyze the characteristic forms of the inshore profile. Later we analyzed local topographic relief characteristics by assuming the existence of a bar-trough morphology and by using a counting procedure.

Although traditional interest in the inshore region has centered on bar-trough morphology, few analyses have been designed to determine major modes of variability. Sonu (1968) showed that changes in the inshore region could be represented as transitions in a stochastic system. However no one has described the major systematic and sequential form changes in inshore morphology along extensive reaches of the coast. The large data source used in this study enabled us to estimate form changes in the inshore area along much of the east and Gulf coasts of the United States. Since the sampling is spatially and temporally irregular, any conclusions based on this data must be within the limiting factors previously discussed.

There are several methods available for treating variation and covariation of observed depths along profiles: 1) Arbitrary forms could be used to characterize slopes, and classifications could be based on the relative frequencies of these characteristics; 2) means and variances of depths at different distances from shore could be used to describe the range of slopes. However, for minimizing least square errors with the fewest terms, a principal component analysis gives optimal representation of a spatial field (Lorenz 1956; Gilman 1957; and Kutzbach 1967).

The utility of eigenvectors as the representation of characteristic forms and regional trends of bathymetric organization is demonstrated here. We have in part used Kutzbach's approach (1967).

Given a set of N observations on M variables, an M by N observation matrix, G, can be formed in which the n^{th} column represents an M component observation vector, $\vec{g}_n$. Here the i^{th} variable in the observation is the depth at the i^{th} point on the profile. Applying a simple translation to the variables, one obtains

$$f_{in} = g_{in} - b_i$$

where b_i is the mean of the i^{th} variable and f_{in} is the i^{th} component of a new observation vector, $\vec{f}$. A new M by N observation matrix, F, is then formed in which the column vectors, $\vec{f}$, now represent observations in terms of deviations from the mean. To determine characteristic forms among variables, one seeks the form which most resembles all observations where resemblance is based on the squared and normalized inner product between each observation and the characteristic form. This is accomplished by maximizing the quantity

$$(\vec{e}'F)^2 N^{-1}/\vec{e}\vec{e}' \qquad (1)$$

subject to the constraint

$$\vec{e}\vec{e}' = 1 \tag{2}$$

where $\vec{e}$ is an M - component vector representing the characteristic form with maximal resemblance and where primed quantities are transpositions. Defining R as the covariance matrix,

$$R = N^{-1} F'F, \tag{3}$$

and substituting (3) into (1) yields

$$\vec{e}'R\vec{e} \tag{4}$$

as the quantity to be maximized. Using a Lagrange multiplier, λ, maximization of (1) under the orthogonality condition (2) is equivalent to the unconditional maximization of

$$\vec{e}'R\vec{e} - \lambda\vec{e}'\vec{e},$$

which on differentiation produces

$$(R - \lambda I)\ \vec{e} = 0, \tag{5}$$

where I is the identity matrix on the same order as R, as the equation to be solved to obtain the vector $\vec{e}$ with maximal resemblance to all observations. Solution of (5) yields not one but a set of values, λ_i (i=1,M), and a corresponding set of vectors, $\vec{e}_i$(i=1,M). The λ_i and $\vec{e}_i$ are the eigenvalues and eigenvectors, respectively, of the covariance matrix, R. If the λ_i are selected in descending order, the corresponding eigenvectors represent the characteristic forms which successively contain the highest resemblance to all observations under the constraint that each is uncorrelated with previously calculated eigenvectors. Additionally, each eigenvalue is interpretable as that part of the variance explained by its associated eigenvector.

Using the inner product between an observation and an eigenvector to provide a measure of similarity,

$$W_{in} = \vec{e}'_i\vec{f}_n \tag{6}$$

is obtained, where W_{in} is the weighting of the n^{th} observation on the i^{th} eigenvector. For the complete observation matrix and the full set of eigenvectors, (6) becomes

$$W = E'F. \tag{7}$$

Since E is an orthogonal matrix, (7) can be rewritten as

$$F = EW. \tag{8}$$

To represent the original observation matrix, the variable means must be added to (8),

$$G = EW + B$$

where B is a matrix containing N columns of the means of the M variables.

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A consequence of selecting eigenvalues in order of descending magnitude is that 1) the first eigenvector explains the maximum possible variance for any one-dimensional representation of the observations; 2) the combination of the first and second eigenvectors explains the maximum possible variance for any two-dimensional representation of the observations; 3) in general, the combination of the first K (K<M) eigenvectors explains the maximum possible variance for any K-dimensional representation of the observations. Hence, the eigenvector space is the optimal representation of the observation matrix, in the sense of least square errors, for any number of terms. In highly organized data fields, the number of eigenvectors required to give a good approximation to the set of observations may be considerably lower than M. A criteria of goodness of fit often used is the percent variance explained. Thus, it is possible to write

$$\hat{g}_n \approx \sum_{i=1}^{K} W_{in} e_i + \vec{b}$$

where $\hat{g}_n$ is an approximation to the n^{th} observation and $\vec{b}$ is a column vector containing the variable means.

To apply this procedure to the analysis of inshore bathymetry, a 26 by 26 correlation matrix was calculated from the set of 26-point inshore transects. The correlation matrix, rather than the covariance matrix, was used to prevent the points farthest offshore from dominating the total variance and consequently from dominating the eigenvector forms. This represents a transformation of the r_{ij}th element of R to the normalized form

$$r_{ij} = N^{-1} \Sigma f_{in} f_{jn} / (\Sigma f_{in}^2 \sum f_{jn}^2)^{\frac{1}{2}} .$$

The analogy to Equation 6 for a measure of similarity between an observation and an eigenvector of this correlation matrix is given by

$$W_{in} = \sum_{j=1}^{26} f \; e_{ij} \; f_{jn}/\sigma_j \qquad (9)$$

where σ_j is the standard deviation of the j^{th} variable. By combining (3), (5), and (7), it can be shown that the row vectors of the matrix of weightings, W, are orthogonal. This property insures that zero correlation exists for the set of eigenvector weights along a coast.

Characteristic functions, or eigenvectors, have several desirable statistical properties. Each eigenvector calculated from a data matrix is orthogonal (independent) to all other eigenvectors calculated from that matrix. In the manner of calculation, eigenvectors are generated sequentially according to the magnitude of the variance by each eigenvector calculated from the original data; that is, the first eigenvector explains the largest percentage of the total variance, and the second eigenvector, the second largest percentage of the total variance, etc. If the original data set contains 26 variables then 26 eigenvectors may be calculated; however unless the total variance is equally distributed among all 26 eigenvectors, a few eigenvectors will account for most of the total variance in the original input data. Thus a problem of 26 dimensions (26 variables) may be reduced to a problem of only a few dimensions. For example, in this study a 26-dimension problem is reduced to one of 3 dimensions (new eigenvector variables) with a retention of over 97% of the total variance of the original data set. (The remainder may be considered a noise in the original data.) In addition, the original elements of the data matrix, a profile in this study, may be approximated as the weighted sums of the significant eigenvectors plus the mean.

Each eigenvector is best understood as a plot of its multipliers. In the case of 26 variables each eigenvector consists of 26 such multipliers. In this study we have analyzed bathymetric profiles of 26 depth variables. The form of the plotted 26 multipliers of each calculated eigenvector thus represents the characteristic ways in which the profiles depart from the mean of all sampled profiles. Physical interpretation of the departures from the mean are examined in this form.

RESULTS

Profile Variation Along the Coast

To assess the variations in inshore profile form along the United States Atlantic and Gulf coasts, we conducted the four separate eigenvector analyses which follow. These four analyses will be discussed simultaneously because they provide the same perspective of bathymetric variation along the coast.

1) An analysis of the Profiles 1-35, covering the barrier-island coast of Long Island.

2) An analysis of Profiles 36-77, covering a section of the New Jersey coast similar in length to the Long Island stretch.

3) A pooled analysis of Profiles 1-77.

4) An analysis of Profiles 1-504, the basic data set.

The first three eigenvectors calculated in each of the four analyses we conducted account for at least 87% of the total variance (Table 1). This percentage of total variance explained ranges from a low of 87.1% for the Long Island profiles to 97.3% for the New Jersey profiles. The first eigenvector alone accounts for 60.7% of the variance along the Long Island coast and 86.3% of the variance along the New Jersey coast. Thus the first eigenvector for the New Jersey coast explains almost as much of the total variance as do the first three eigenvectors for the Long Island coast. Clearly, bathymetric variation along the Long Island coast is significantly more complex than that along the New Jersey coast.

When we pooled and analyzed the Long Island and New Jersey data (Profiles 1-77), the resultant distribution among eigenvectors of total variance explained was nearly the same as when we used the total sample of profiles (Profiles 1-504). The size of the sample used in these analyses is therefore an important consideration in the analytical design.

Although inspection of the percentage of variance explained by a sequence of eigenvectors provides insight into the organizational complexity of the profiles studied, the physical meaning of each eigenvector is central to the questions posed in this study. Since we extracted the mean of all profiles from each profile studied (Fig. 3) to permit analyses of the characteristic departures from the mean, we will first examine the form of the mean profiles.

The mean of Profiles 1-35 (Long Island) exhibits a convex upward curvature seaward of 480-feet (145 m) from MLW, suggesting a bar-like feature. In contrast the mean for the New Jersey coast (Profiles 36-77) is slightly concave upward throughout and does not suggest a bar-like feature. The mean profile for the entire basic profile set (Profiles 1-504) is rather flat when compared with the means of the Long Island and New Jersey coasts with a general absence of clearly defined bar-trough morphology. Since this absence is masked by the mean, bar-trough morphology must be considered statistically as a departure from the mean. Therefore in the eigenvector analyses we subtracted the mean of all profiles leaving the residual departures from the mean for analyses.

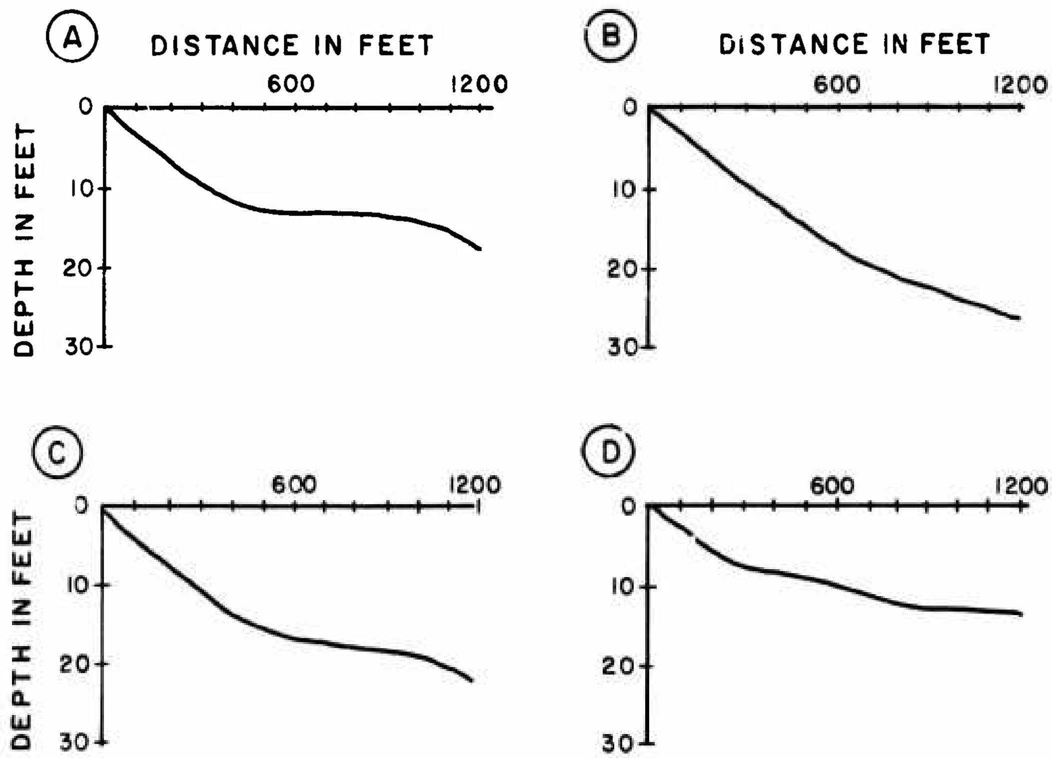
TABLE 1

Percentage of Variance Explained for all Profiles by Eigenvector 1, Eigenvector 2, and Eigenvector 3

Profile Set	Percentages of Variance Explained		
	E_1	E_2	E_3
Profiles 1-35 (Long Island)	60.7	17.0	9.4
Profiles 36-77 (New Jersey)	86.3	9.0	2.0
Profiles 1-77 (Long Island and New Jersey)	75.8	17.2	3.0
Profiles 1-504 (U.S. Atlantic and Gulf coasts, beginning at Long Island)	76.6	15.3	3.5

FIGURE 3

Mean Profiles



Mean profiles for: A. Transects 1-35
B. Transects 36-77
C. Transects 1-77
D. Transects 1-504

In the analyses the first eigenvector of the New Jersey profiles was somewhat more complex than the first eigenvector of the Long Island profiles or the basic data set of 504 profiles (Fig. 4). For the New Jersey data samples, the eigenvector multipliers immediately landward of approximately 450 feet (135 m) from MLW are larger than those seaward of the 450-foot (135 m) mark. Thus a profile from the New Jersey coast with a positive weighting on Eigenvector 1 (E_1) deepens the area landward of the 450-foot (135 m) mark more than it does seaward of this mark. Under these conditions a convex upward curvature seaward of 450 feet (135 m) results in and is indicative of a bar-like morphology. Since Eigenvector 2 (E_2) governs some aspects of profile curvature along the New Jersey coast but explains only about half the variance there that E_2 explains elsewhere, some of the profile curvature variance may be correlated with the slope variable in the New Jersey area. This possible correlation would account for the relatively large (86.3%) percentage of variance being explained here by E_1.

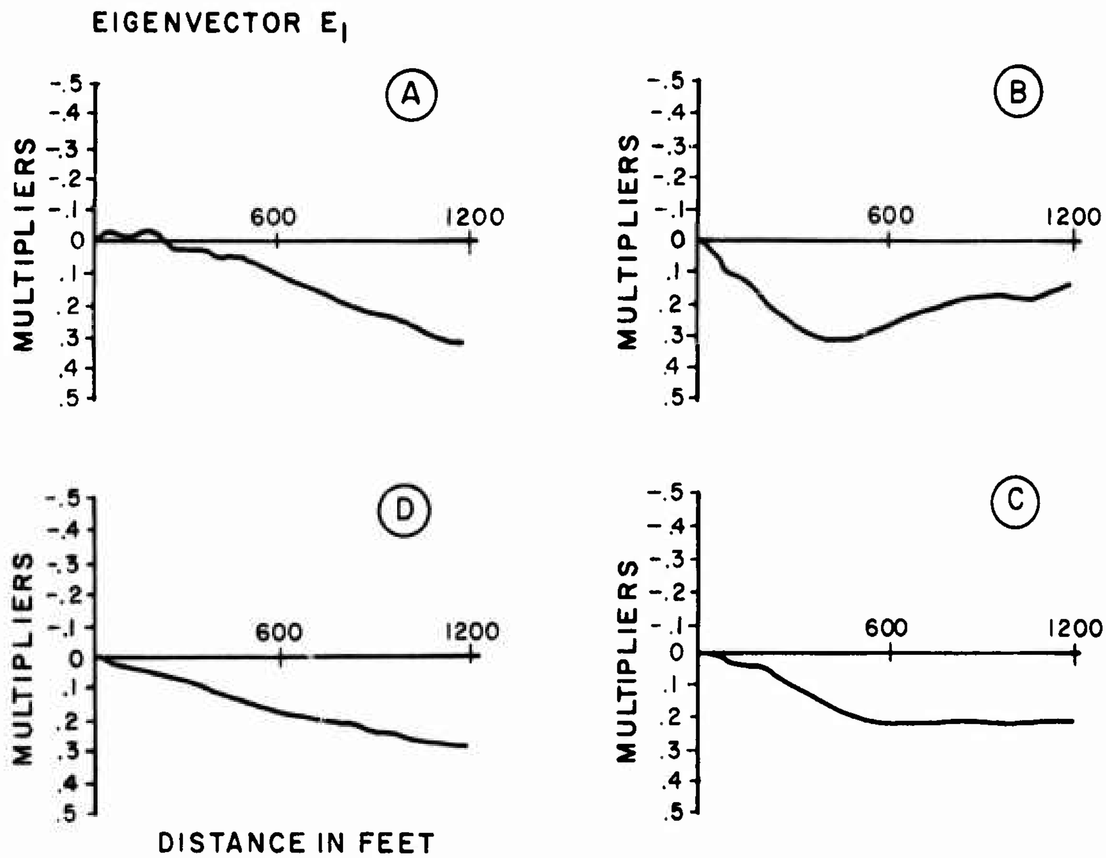
In variance explained the profile slope is the most significant attribute of profile variation from the mean as indicated by the physical interpretation of E_1. The multipliers of the first eigenvectors for each of the four profile sets analyzed (Fig. 4) have a positive sign throughout the profile. Therefore when E_1 is weighted positively for a given profile, there is an increasing positive departure from the mean depth with distance offshore; i.e., the slope of the profile is steeper than the mean. When E_1 is negatively weighted for a given profile, there is a negative departure from the mean, the slope of the profile decreases, flattening the profile. Thus the first new variable (E_1) is a measure of profile slope with respect to the mean. For the 504 profiles studied, 76.6% of the topographic variance from the mean may be characterized in terms of the slope departure. Slope and curvature departures from the mean were contained in separate and independent eigenvectors for the basic data set because the partial correlation noted along the New Jersey coast did not occur systematically throughout the 504 profiles.

Both positive and negative multipliers characterize the form of the second eigenvector and are systematically organized along the profile (Fig. 5). In the shoreward portion of the profile, negative multipliers occur with a maximum about 450 feet (135 m) from MLW; seaward of about 720 feet (220 m) there are positive multipliers. This pattern of multipliers exists for each of the four sets of profiles studied. Thus if a given profile has a positive weight for E_2, a convex upward curvature characterizes the profile seaward of 720 feet (220 m). Therefore a positive weighting on E_2 indicates a bar-like feature (convex upward profile curvature) centered about 450 feet (135 m) offshore. If a negative weighting is applied to E_2, the profile landward of 720 feet (220 m) exhibits a concave upward curvature centered at about the 450-foot (135 m) mark and a convex upward curvature seaward of 720 feet (220 m). Morphologically such a pattern might be characterized as a trough at 450 feet (135 m) and a bar seaward of 720 feet (220 m). E_2 thus characterizes part of the profile curvature departures from the mean.

Eigenvector 3 (E_3) also characterizes profile curvature departures from the mean (Fig. 6). Landward of the 450-foot (135 m) mark there are positive multipliers with a maximum centered about 200 feet (60 m) offshore, negative multipliers are between 450 and 900 feet (135 and 275 m) with a maximum centered at 720 feet (220 m), and positive multipliers occur again seaward of about 900 feet (275 m). Profiles with positive weightings on E_3 are characterized by a concave upward curvature between MLW and 450 feet (135 m), a convex upward curvature between 450 and 900

FIGURE 4

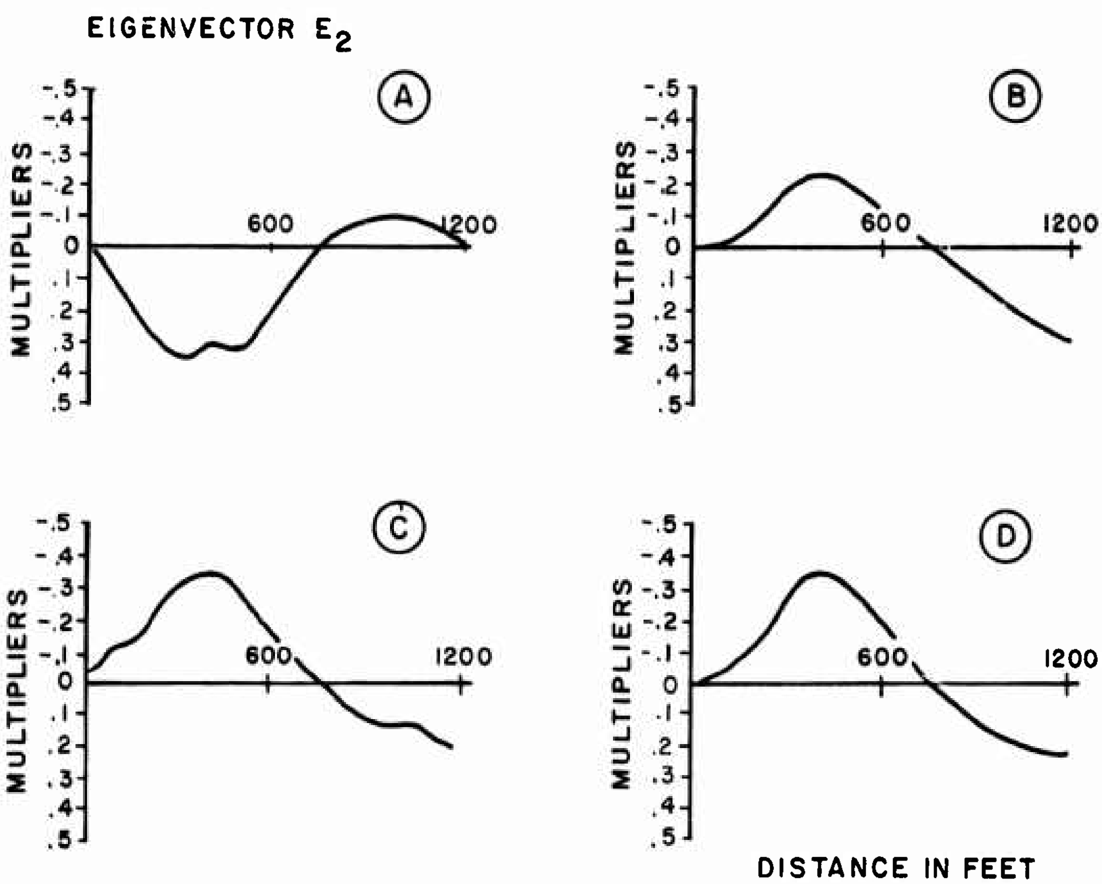
Eigenvector 1 Multipliers



E_1 multipliers for:
A. Transects 1-35
B. Transects 36-77
C. Transects 1-77
D. Transects 1-504

FIGURE 5

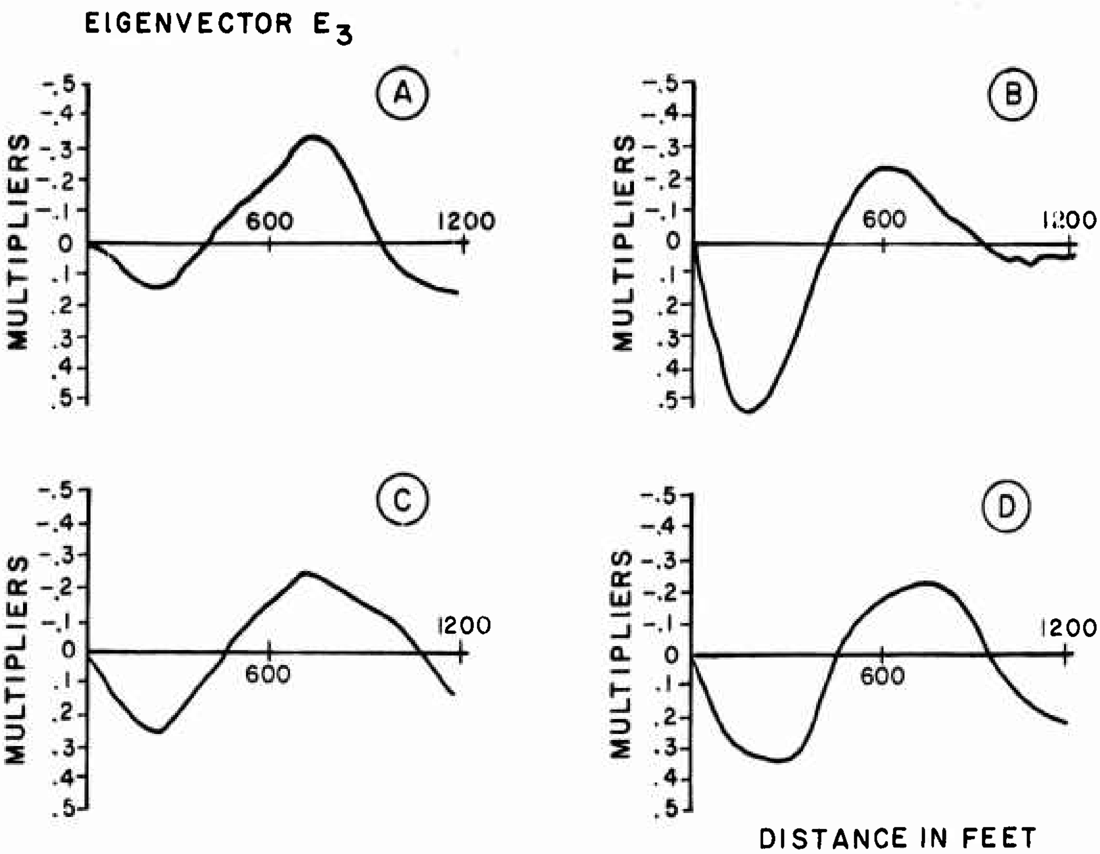
Eigenvector 2 Multipliers



E_2 multipliers for: A. Transects 1-35
B. Transects 36-77
C. Transects 1-77
D. Transects 1-504

FIGURE 6

Eigenvector 3 Multipliers



E_3 multipliers for: A. Transects 1-35
B. Transects 36-77
C. Transects 1-77
D. Transects 1-504

feet (135 m and 275 m), and a concave upward curvature seaward of 900 feet (275 m); or morphologically, a trough centered around 200 feet (60 m) and a bar centered around 720 feet (220 m). Conversely when E_3 is negatively weighted, there will be a bar at 200 feet (60 m) and a trough at 720 feet (220 m).

Great care must be exercised in discussing individual eigenvectors in morphological terms. Since E_2 and E_3 multipliers vary in magnitude and sign along the length of the profile, the additive effect of these eigenvectors may in the aggregate enhance or reduce topographic departures from the mean in such a way as to bear little resemblance to the eigenvector multipliers taken singly. It must be remembered that a complete description of the profile in terms of the eigenvectors requires the summation of the mean and each of the eigenvectors with appropriate weightings. In spite of this apparent difficulty, the independence (or orthogonality) of each eigenvector clearly suggests that there is more than one mode of curvature departures from the mean. In E_2 the distance between zero multiplier values, including the shoreline, is approximately 720 feet (220 m) and in E_3, 450 feet (135 m). It would thus appear that E_2 and E_3 are explaining different length scales of topographic variance. If there are two scales of features in inshore bathymetry due to differences in hydrodynamical environments and if the hydrodynamic environment varies through time, the additive effect of the two eigenvectors characterizing the attribute of curvature may aid in explaining seaward and landward shifts in bar-trough morphology. Unfortunately the data available to conduct this study was not systematically collected: Time within the tidal cycle and within the year were not controlled and must be considered random. These constraints preclude systematic study of the causation of these bathymetric variations.

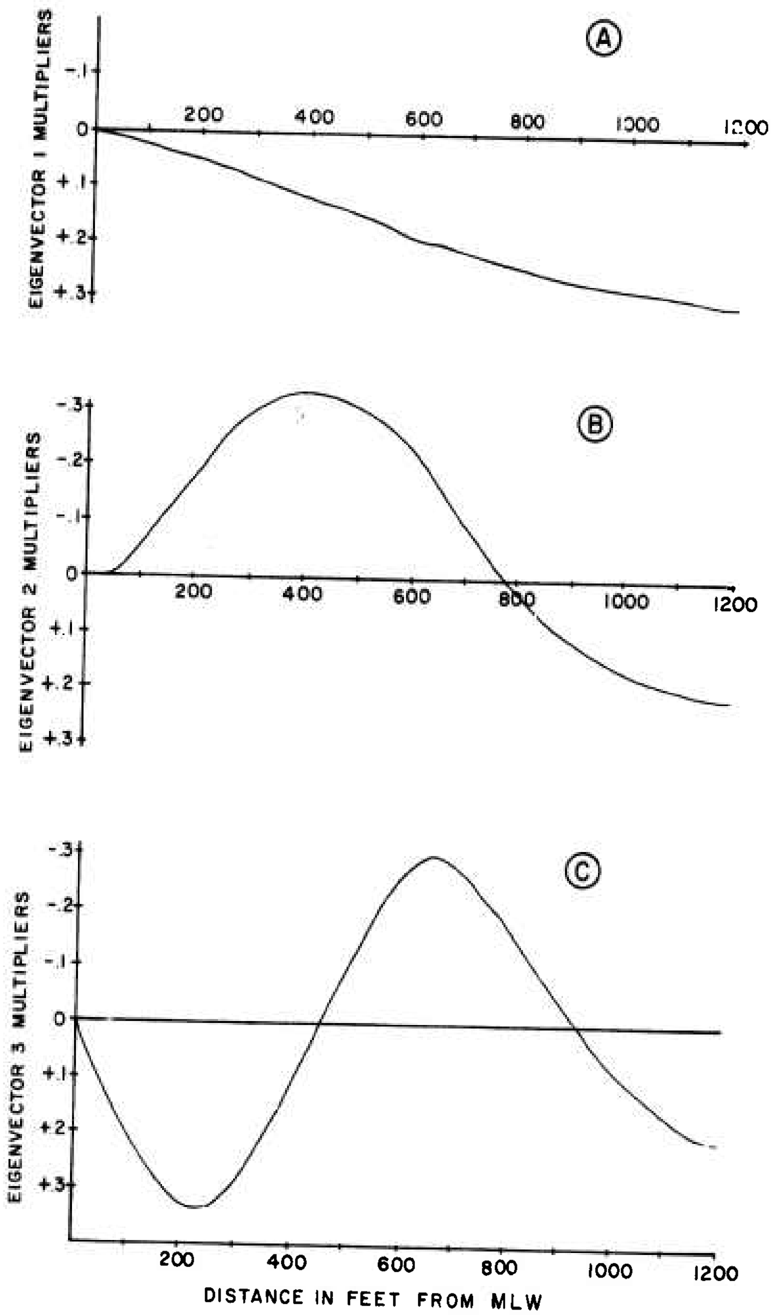
Variations of the Inshore Slope

E_1 of the basic data set (Profiles 1-504) characterizing departures in slope from the mean accounted for 76.6% of the total variance of the 504-profile sample. As noted earlier, a positive weighting on E_1 indicates slopes steeper than the mean and a negative weighting, slopes shallower than the mean (Fig. 7).

Along the Long Island coast (Profiles 1-35), inshore slopes at the eastern end of the island are steeper than the mean and toward the west shallower than the mean (Fig. 8). However, the magnitude of the eigenvector weightings indicates that inshore slopes for Long Island closely approximate that of the mean.

Profiles 36-136 (Sandy Hook, New Jersey, to Cape Hatteras, North Carolina) are positively weighted throughout, indicating inshore slopes steeper than the mean. In general there is a north-to-south trend, with the steepest slopes to the north and the shallowest to the south. The area south of Cape Hatteras (Profiles 137-157) is dominated by negative weightings and slopes shallower than the mean. Slopes along the Georgia and north Florida coasts (Profiles 158-214) are generally near the mean except in Profiles 190-200 where steeper slopes are noted. From Hutchinson Island to south of Lake Worth Inlet (Profiles 237 to 292) shallow slopes are characteristic; south of this point to Key West (Profiles 293 to 395) slopes are generally steeper than the mean. From Key West along the Gulf coast (Profiles 405 to 504), inshore slopes are characteristically shallower than the mean.

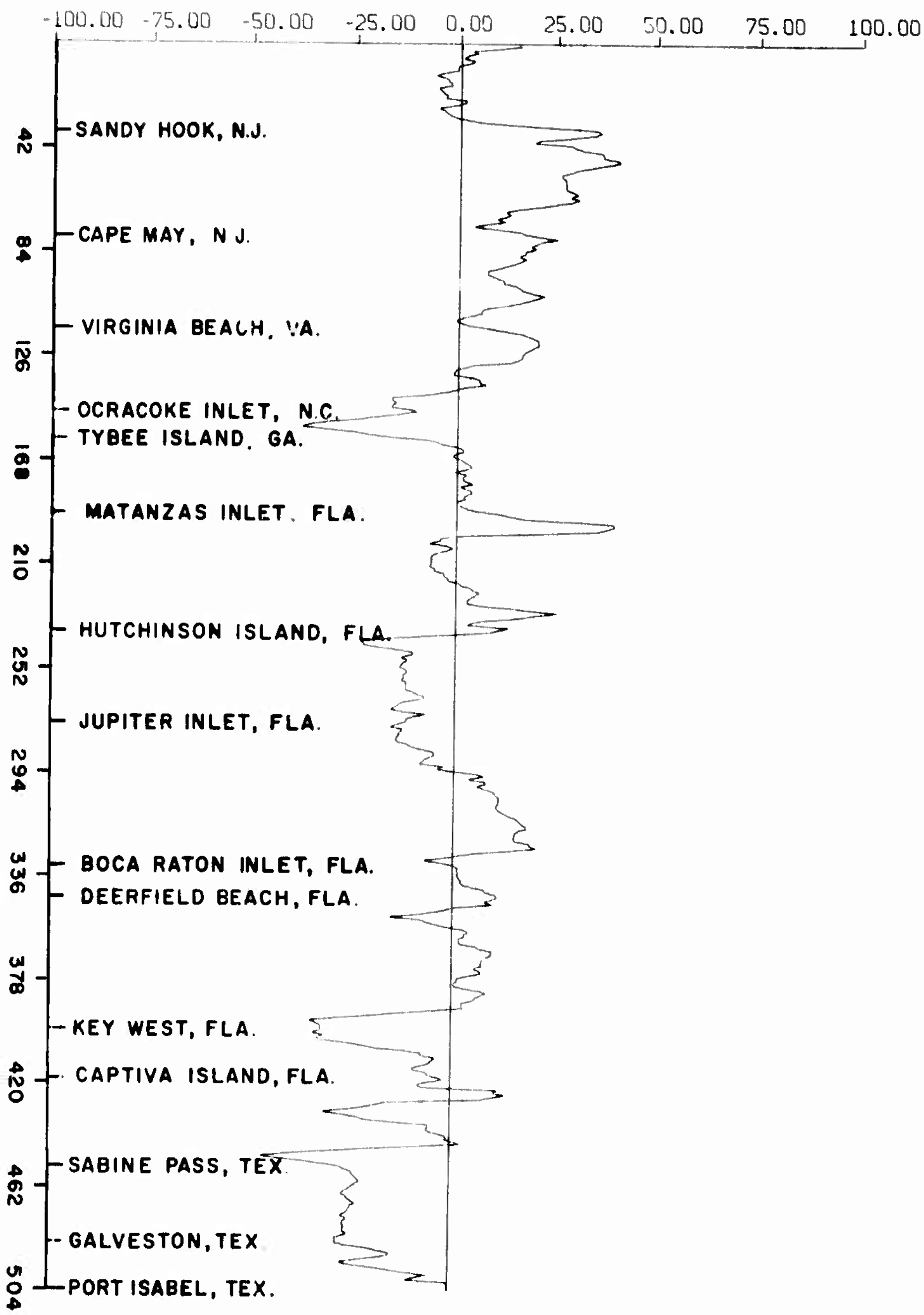
FIGURE 7



E_1, E_2, E_3 multiplier plots for the basic data set (Transect 1-504).

FIGURE 8

Eigenvector 1 Weights



E_1 weights along the coast were smoothed using a 5-point running mean.

Variations in Profile Curvature Along the Coast

E_2 and E_3 accounted for 15.3% and 3.5%, respectively, of variance associated with curvature departures from the profile slope (the mean plus E_1). The stratification of variance into two separate eigenvectors due to curvature elements of the profile is important because the two eigenvectors are uncorrelated, or orthogonal. This implies that there are two independent modes of curvilinear form variation in the profiles studied.

The most noteworthy element of the along-the-coast magnitudes of E_2 weightings (Fig. 9) is the trend from negative to positive weightings between Long Island and Cape Hatteras. From Long Island to New Jersey (Profiles 1-63) the curvature is concave upward although to the south (Profiles 64-145) the curvature is convex upward. In morphology, this would indicate that, as one moves southward along this particular coastal reach, a bar-like feature is positioned progressively shoreward. South of Cape Hatteras as far as northern Florida (Profiles 145-180), the trend is reversed, with negative weightings indicating a more offshore position of the convex upward curvature element. South of Matanzas Inlet to Hutchinson Island (Profiles 200 to 238), the Florida coast resembles that of Hatteras Island, with a "bar" positioned closer to the shoreline.

E_2 weightings along most of the Gulf coast (Profiles 405-504) are low except for the significant negative weighting along the central west coast of Florida (Profiles 425-440).

The plot-by-profile of E_3 weightings (Fig. 10) indicates significant variation along the coast. There are negative weightings from Long Island to Virginia Beach (Profiles 30-117); from Cape Hatteras to Tybee Island (Profiles 140-159); from south of Matanzas Inlet to Hutchinson Island (Profiles 195-238); around West Palm Beach (Profiles 300-314); and along the Gulf coast (Profiles 405-504). There are extensive reaches showing positive E_3 weightings from Virginia Beach to Ocracoke Inlet (Profiles 117-145); from Hutchinson Island to north of West Palm Beach (Profiles 238-294); and from Deerfield Beach to north of Golden Beach (Profiles 343-388).

Profile Forms and Bar Occurrences

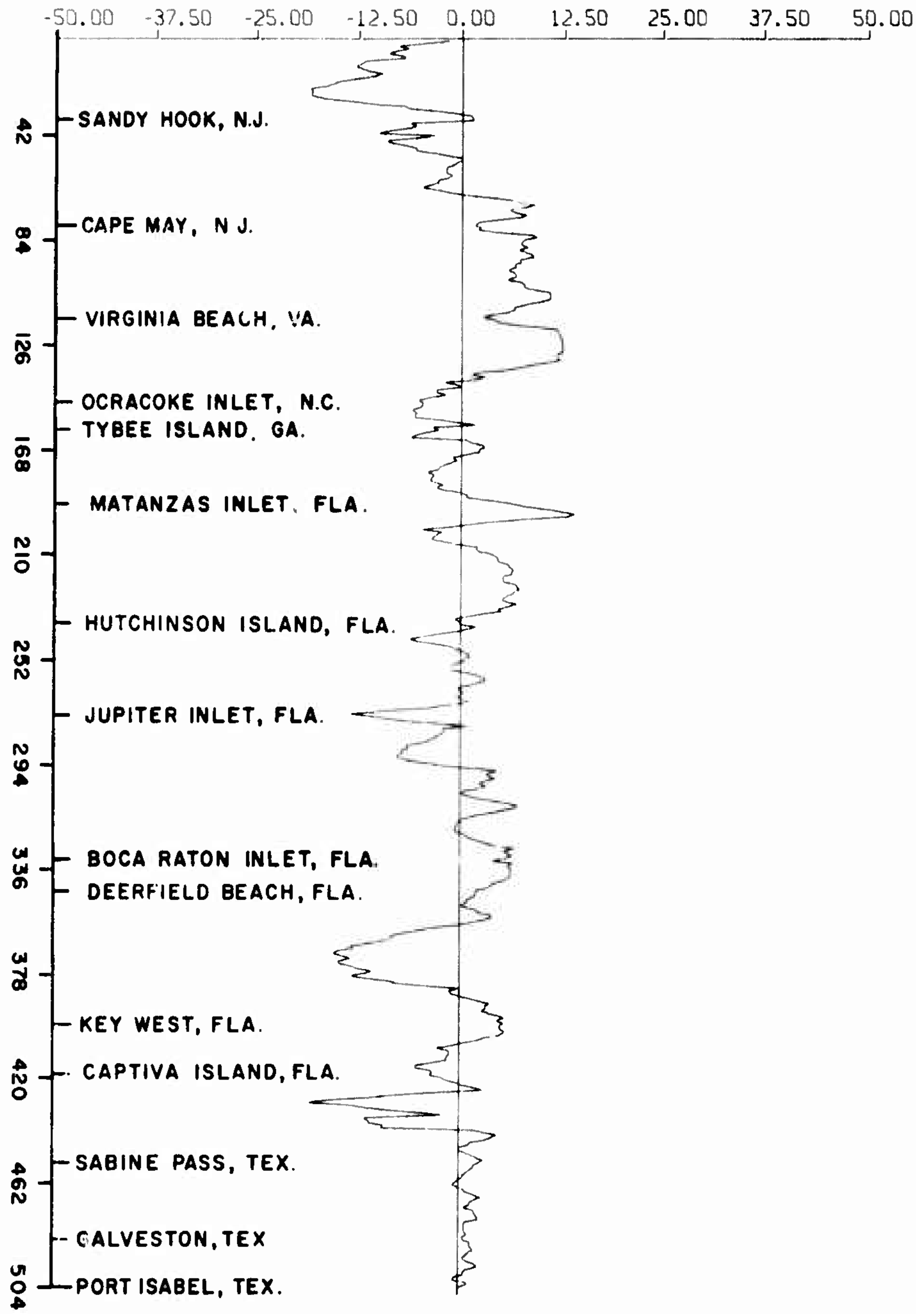
Throughout the preceding discussion, we have been careful with the physical interpretation of the eigenvector forms. "Convex" and "concave upward profile curvatures" are terms used and are occasionally described as bar-like features. To establish the relationship between these terms and the bar-and-trough terminology in morphologic literature, we conducted additional analyses of the 504 profiles of the basic data set. Traditionally measured parameters (bar-crest height, distance offshore, and the number of bars in a profile) were collected for each of the 504 profiles in the study set and a working definition of a bar was derived.

A bar of height "h" is defined as a local topographic maximum in the profile where the difference between that maximum and the preceding minimum is greater than the specified height "h" (Fig. 11). The distance offshore to the bar is the distance from the zero point of the profile to that point at which the profile leveled off.

Since we recorded depths every 50 feet (15 m) the distance offshore is always a multiple of 50 feet (15 m). The number of bars in a profile is, therefore, defined as the total number of local maxima. Any given

FIGURE 9

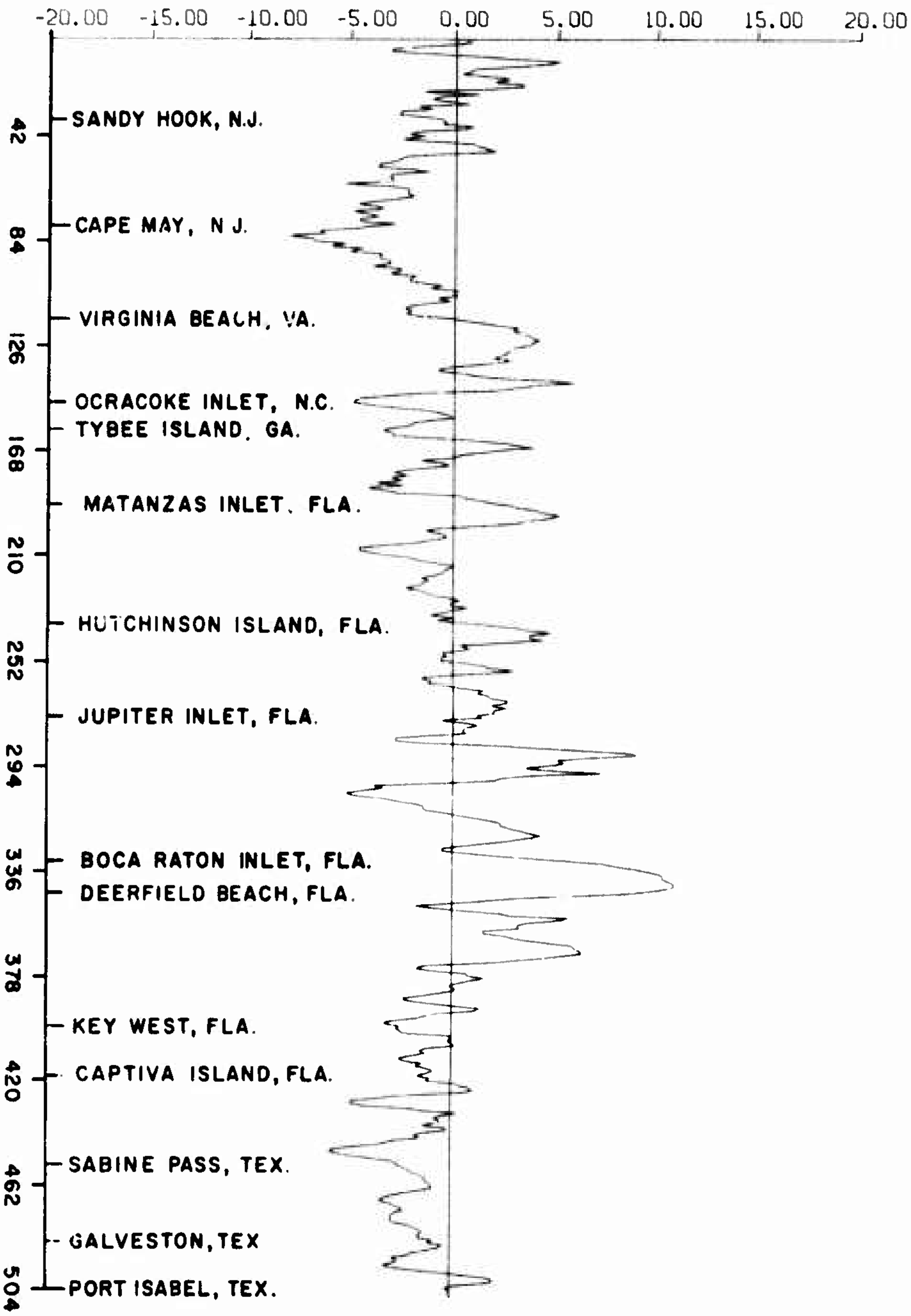
Eigenvector 2 Weights



E_2 weights along the coast were smoothed using a 5-point running mean.

FIGURE 10

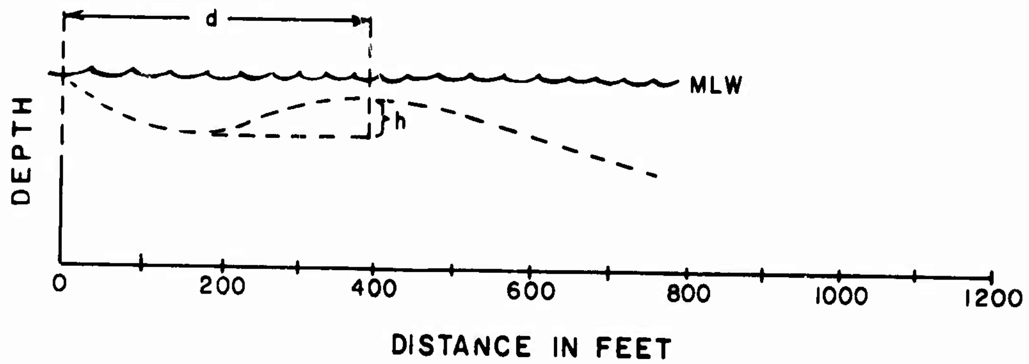
Eigenvector 3 Weights



E_3 weights along the coast were smoothed using a 5-point running mean.

FIGURE 11

Definition of Bar-Height Criterion



profile can have a different number of bars depending on the value chosen for "h". The bars defined by this analysis are necessarily broad features, thereby reducing the probability of either incorrectly selecting a minor feature or of an error in the data during the bar-counting processes.

An inner bar was not detected within 100 feet (30 m) of shore since the first sample point is 50 feet (15 m) and therefore cannot be a maximum. Furthermore, the inner bar is not picked up if it is less than 50 feet (15 m) across or "h" feet deep. Therefore, it is probable that in many cases these analyses failed to distinguish an inner bar system of the type described. This means that the analyses concentrated on broad features or elements of the profile and are, therefore, suitable criteria for assessing the physical significance of the eigenvector forms.

In the analyses for this study we used a bar-height criterion of 2.0 feet (60 cm) and 0.1 foot (3 cm). Because height differences of 0.1 foot (3 cm) are equivalent to the stated accuracy of the original data, special comment is needed for the 0.1-foot (3 cm) bar-height criterion. Given that the mean slope for the profiles studied is 0.6 feet (20 cm) in the verticle over a horizontal distance of 50 feet (15 m), a positive topographic difference of 0.1 foot (3 cm) constitutes a 0.7-foot (20 cm) departure from the mean. Consequently a bar-height criterion of 0.1 foot (3 cm) constitutes a considerable mass of sand with respect to mean slope of the profile. In addition the results of our analyses using both the 2-foot (60 cm) and 0.1-foot (3 cm) height criterion are not different nor is there more scatter in the plots using the 0.1-foot (3 cm) criterion than that found for the 2.0-foot (60 cm) criterion. We are therefore convinced that the topographic features observed at the 0.1-foot (3 cm) level are bars or bar-like features.

For each of the 504 profiles of the basic data set, we recorded the distance from the shoreline to the bar crest using minimum height criteria of 0.1 and 2.0 feet (3 and 60 cm). Using the 0.1 and 2.0 feet (3 and 60 cm) height criteria, 339 and 156 of 504 profiles had one or more bars, respectively. To assess the relationship between profile curvatures as indicated by E_2 and E_3 and the occurrence of bars along the profile, we plotted the sums of equally weighted combinations of E_2 and E_3 (Fig. 12). The forms of these plots are consistent with the frequency histograms of bar occurrence in terms of distance offshore (Fig. 13). To further substantiate the relationships between the weightings on E_2 and E_3 and the locations of bars along the profiles, we stratified the profiles according to bar location. Using the E_2 and E_3 values for each profile, we then plotted a point in E_2, E_3 space for each profile in each profile class defined by bar location (Figs. 14, 15, and 16).

In each figure the profile weightings on E_2 are on the x axis and the weightings on E_3 on the y axis. Each profile with its respective weightings on E_2 and E_3 is represented as a point in this eigenvector space. At each such point we recorded the distance from the shoreline to the bar crest. Those profiles with bar occurrences between 100 feet and 350 feet (30 m and 105 m) offshore (Fig. 14) and between 400 feet and 750 feet (120 and 230 m) (Fig. 15), and between 800 feet and 1150 feet (245 and 350 m) (Fig. 16) were plotted. These distance intervals were chosen on the basis of the forms of each of the respective eigenvectors. In the case of the first interval, 100 feet to 350 feet (30 to 105 m), a positive weighting on E_2 with a negative weighting on E_3 results in a convex upward curvature. If indeed these convex upward curvature departures from the mean are indicative of a bar in that region, then most of the plotted points would fall in the second quadrant of the graph (Fig. 14). Indeed 58% of all profiles with bars

FIGURE 12

Joint Effects of Eigenvector 2 and Eigenvector 3
Under Various Weighting Combinations

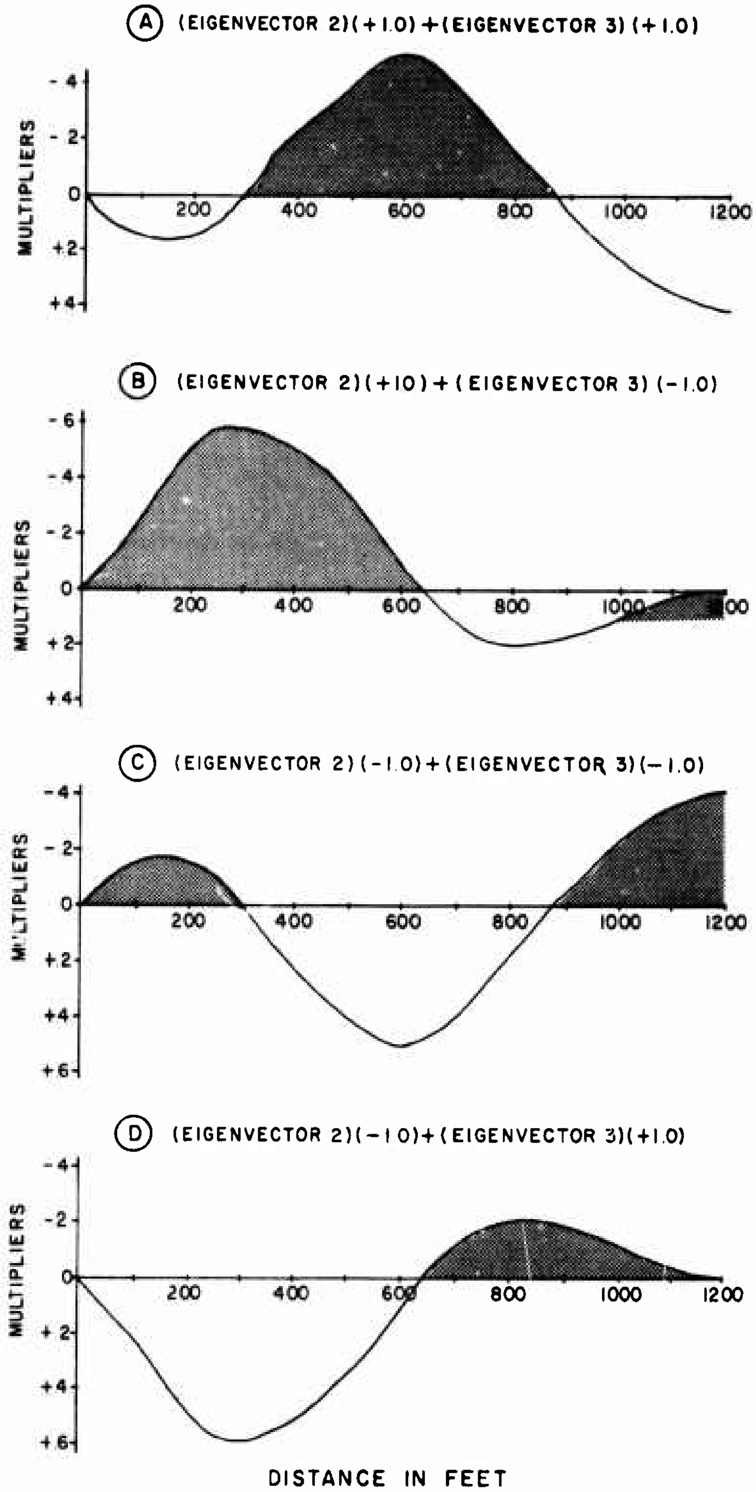


FIGURE 13

Bar Frequencies

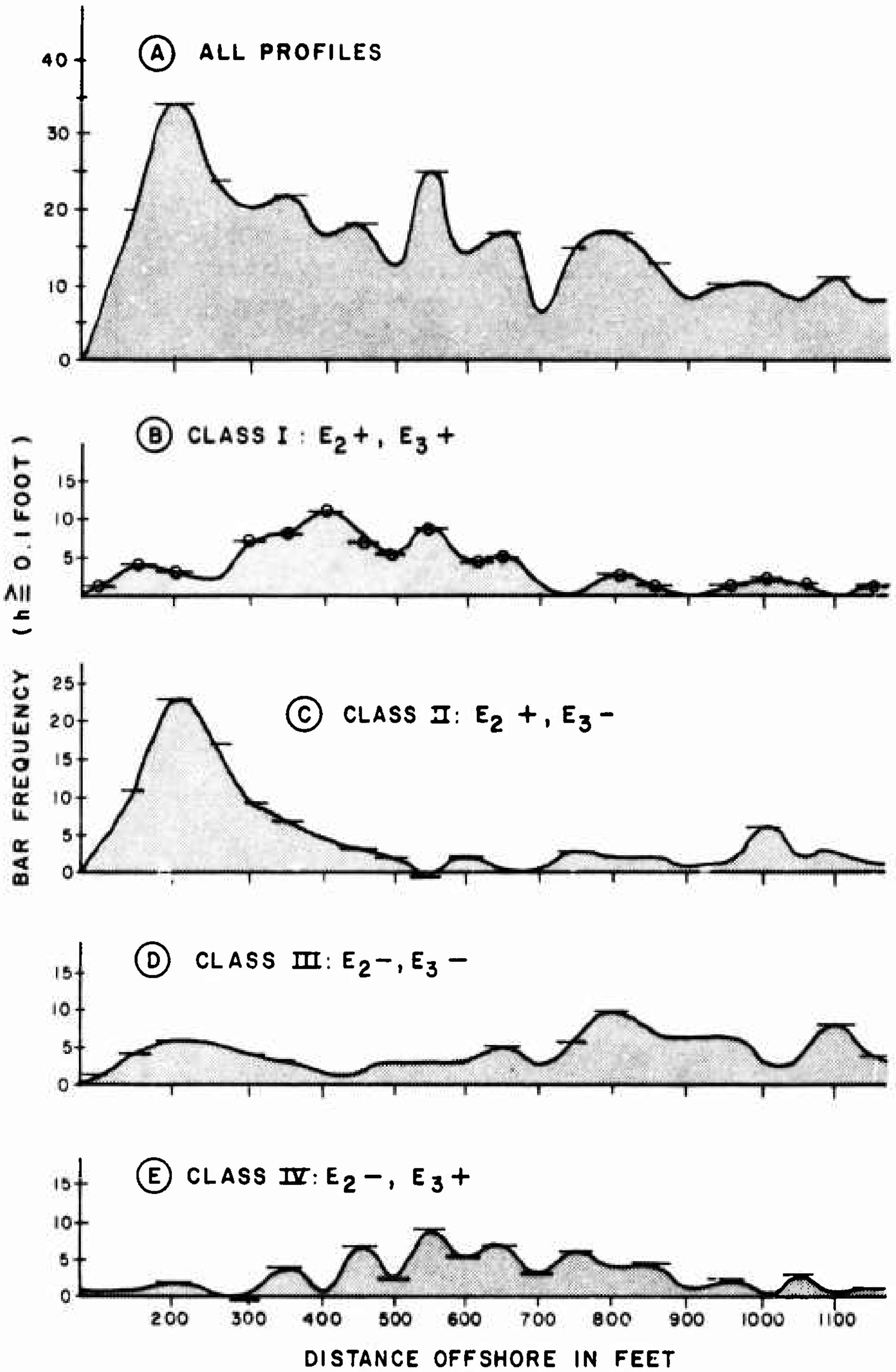
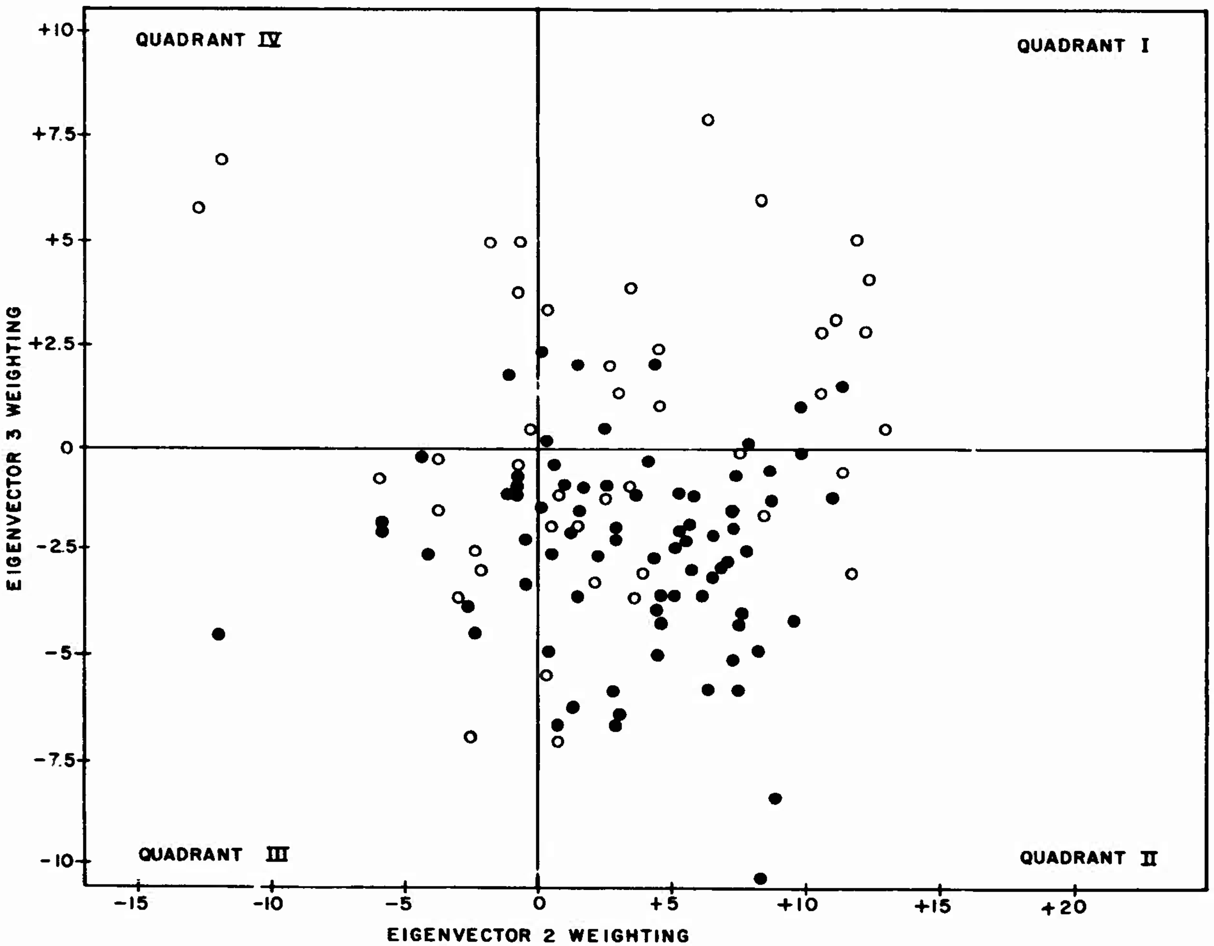


FIGURE 14

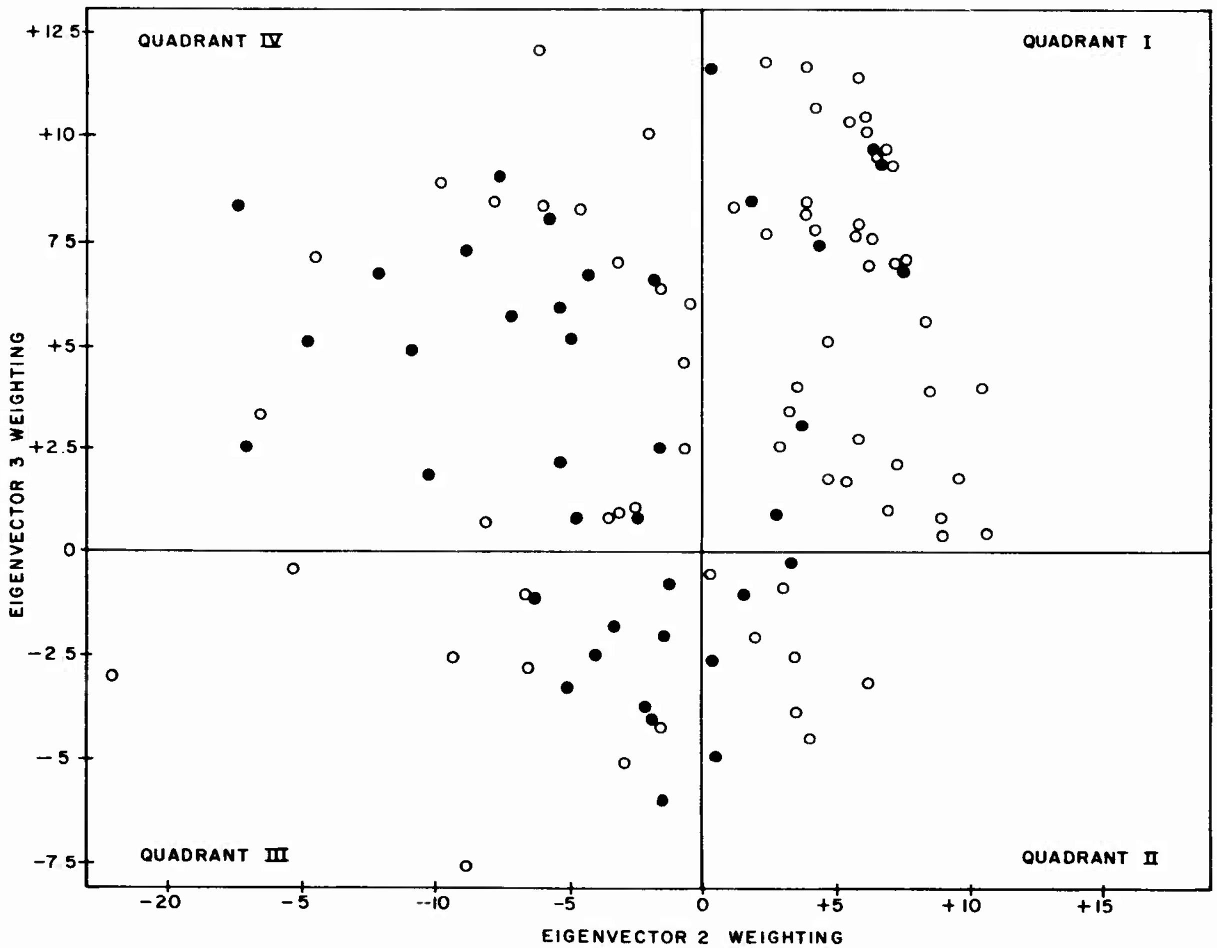
Profile Plots (100-350 ft [20-105 m])



Plot of all profiles in Eigenvector 2, 3 space with a bar (h≥0.1 ft [3 cm]) between 100 and 350 ft (30 and 105 m).
o = bar between 100 and 250 ft (30 and 75 m). x = bar between 300 and 350 ft (90 and 105 m).

FIGURE 15

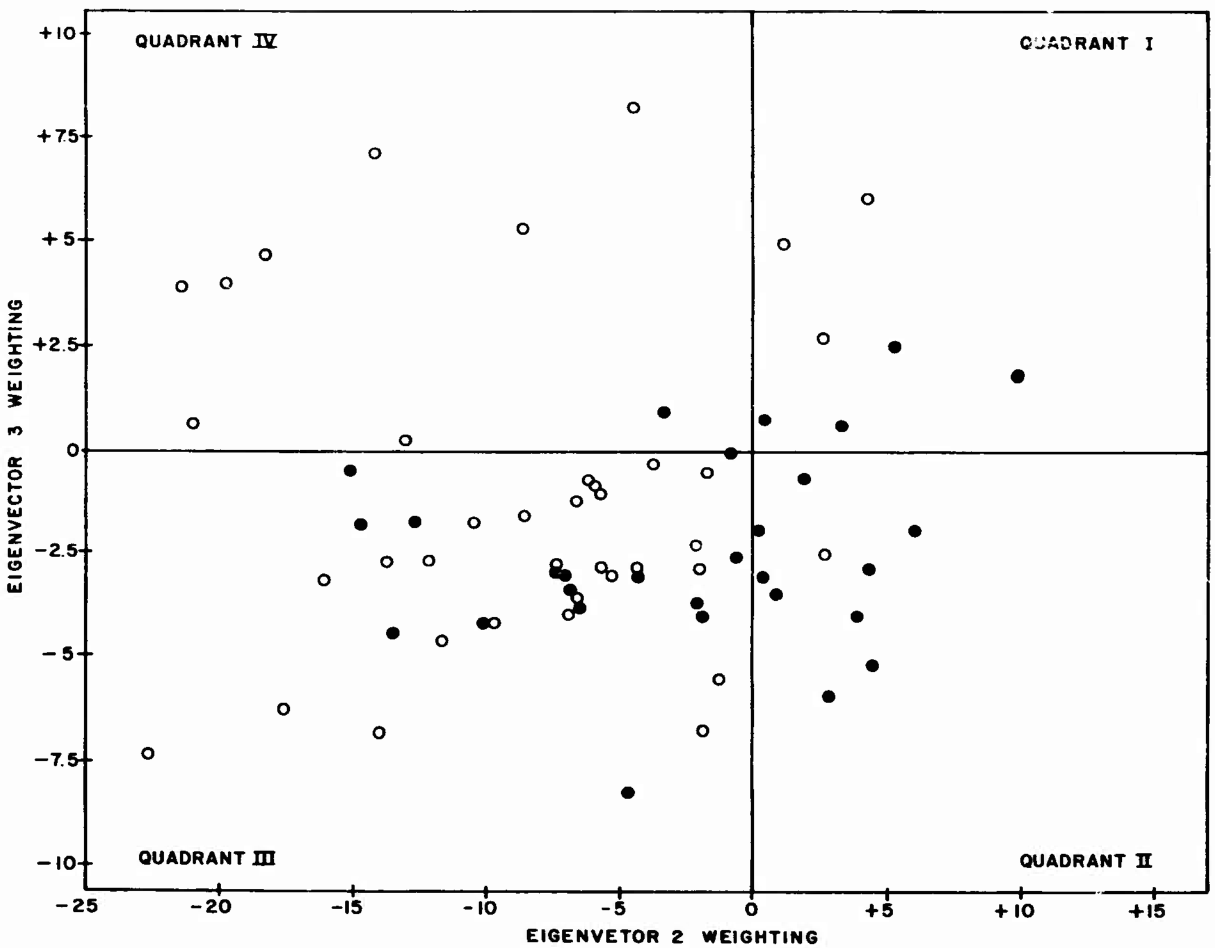
Profile Plots (400-750 ft [120-230 m])



Plot of all profiles in Eigenvector 2,3 space with a bar ($h \geq 0.1$ ft [3 cm]) between 400 and 750 ft (120 and 230 m).
o = bar between 400 and 550 ft (120 and 170 m). x = bar between 600 and 750 ft (180 and 230 m).

FIGURE 16

Profile Plots (800-1150 ft [245-350 m])



Plot of all profiles in Eigenvector 2,3 space with a bar (h≥0.1 ft [3 cm]) between 800 and 1150 ft (245 and 350 m).
o = bar between 800 and 950 ft (245 and 290 m). x = bar between 100 and 1150 ft (305 and 350 m).

within 350 feet (105 m) of the shoreline do fall within this second quadrant. E_3 has negative weightings on 66% and E_2 has positive weightings on 70% of these profiles with bars within 350 feet (105 m) of shore. For these same profiles, 94% have either a positive weighting on E_2, a negative weighting on E_3, or both. In the cases with a positive weighting on E_2 and E_3, the great majority have a bar in the shoreward half of the distance interval (100 feet to 250 feet [30 to 75 m]). This observation is consistent with the form of the respective eigenvectors (Fig. 7); that is when E_3 is positively weighted, the concave upward curvature component is strongest in the 300-foot to 350-foot (90 to 105 m) area and weakest toward the shoreline; concurrently E_2 would add a convex upward curvature in the inner portion. Therefore curvature elements in this region of the profile must be bars.

In the second region of the profile, from 400 feet to 750 feet (120 to 230 m), the situation is more complex with respect to the joint effects of the two eigenvectors. At 400 feet and 450 feet (120 and 135 m) a positive weight on E_2 and a negative weight on E_3 indicate a convex upward curvature. Between 500 feet and 750 feet (150 and 230 m), convex upward curvatures are enhanced by positive weighting on each eigenvector, with E_2 dominating between 500 feet and 600 feet (150 and 185 m) and E_3 dominating between 650 feet and 750 feet (200 and 230 m). In spite of this complexity 75% of the profiles with bars between 400 feet and 750 feet (120 and 230 m) have positive weightings on E_3 (Fig. 15). Furthermore most profiles with a bar between 400 feet and 550 feet (120 and 170 m) are weighted positively on E_2 and most profiles with bars between 600 feet and 750 feet (185 and 230 m) have negative weightings on E_2. Thus in this rather complex region of profiles, the evidence supports the conclusion that the topographic variance explained by the eigenvectors is that associated with bars.

In the third region of the profile, 800 feet to 1150 feet (245 to 350 m), the form of the second eigenvector (Fig. 7) indicates that a negative weighting would imply a convex upward curvature. Of profiles with bars in this region (Fig. 16), 75% have a negative weighting on E_2. Similarly a negative weighting on E_3 favors a bar in this region and 76% of the profiles have negative weightings on E_3. Furthermore 61% of profiles with bars in this region have negative weightings on both E_2 and E_3.

The form of E_3 also suggests that when it is negatively weighted, there can be a bar shoreward of 500 feet (150 m) and another seaward of 950 feet (290 m). One hundred eleven profiles characterized by a negative weighting on E_3 have bars in each of these locations.

The curvature variables, E_2 and E_3, do indeed represent, in a statistical and abstract way, those topographic features which are commonly called bars. At the beginning of this investigation we assumed that most of the profiles would have one or more bars. However, the stringency of the criteria for defining a bar determines the frequency of observing barred profiles. For example, using a 2.0-foot (60 cm) criterion, 156 of the 504 profiles are recorded as barred; however when a 1-foot and 0.1-foot (30 and 3 cm) height criteria are used, 272 and 339 of the profiles have bars, respectively. In addition, the definition of a bar is further constrained by the criterion that there must be a topographic minimum preceding the bar crest. In the case of a sloping surface rather than a horizontal surface, a bar may be present and not meet this criterion. If we assume that the eigenvector representations do accurately define bar-like curvatures in the profile as indicated in these analyses, then the difficulties in defining suitable criteria for bar features is in part circumvented.

Profiles Without Bars

Using the defining criteria of h = 0.1 foot (3 cm), only 111 of the total sample of 504 are devoid of bars. When these 111 profiles are plotted in E_2, E_3 space according to their respective weightings (Fig. 17), only one falls within the fourth quadrant of the figure; that is, with a negative weighting on E_2 and a positive weighting on E_3 (Fig. 12D). When these conditions prevail, the shoreward portion of the profile is significantly deeper than the mean and the mid-section of the profile is significantly shallower than the mean thereby indicating the presence of a bar as defined in this study.

The largest number of profiles without bars are in Quadrant II; that is, when the profile weightings on E_2 are positive and on E_3 negative. Since there must be a topographic minimum preceding a topographic maximum to have a bar on a profile and with the form of the joint effect of equally weighted E_2 and E_3 in the second quadrant (Fig. 12B), the absence of a bar in the profile is a logical conclusion. However when there are bars under these conditions, they occur in the forward portion and at the seaward end of the profile.

Profile Slope and Bar Occurrence

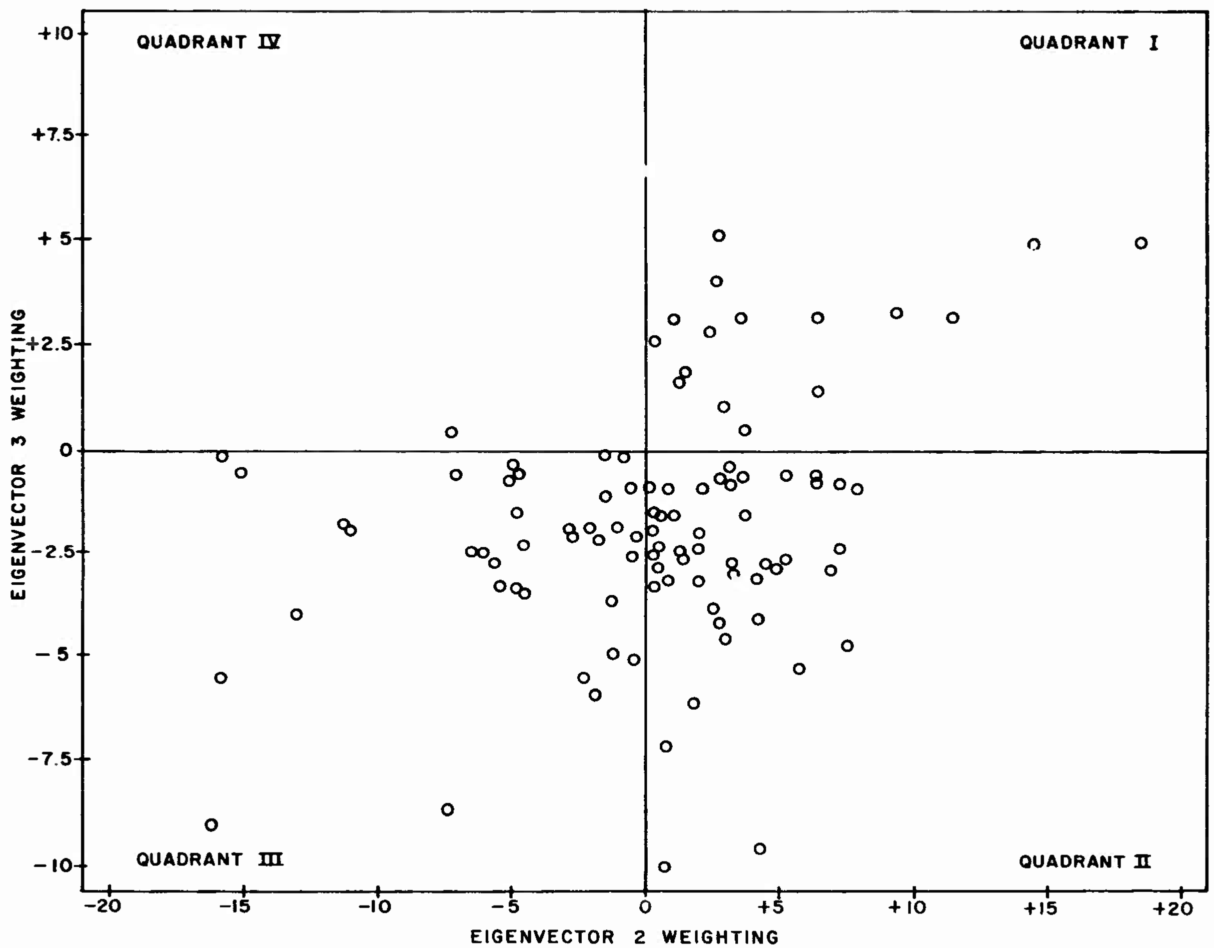
Lau and Travis (1973) found that "the number of bars is likely to increase when the bottom gradient is slight;" Zenkovich (1967) noted that the formation of bars was restricted to a fairly narrow range of slopes (0.02-0.005). In our eigenvector analyses of the 504 profiles of the basic data set, we found that the attribute of profile slope is independent of profile curvature elements; that is, bars. To resolve this apparent contradiction, we compared the weightings on E_1 (the slope variable) with the presence or the absence of bars and with the occurrence of multiple bars using a 2-foot and a 0.1-foot (60 and 3 cm) depth criterion (h) (Figs. 18 and 19).

Of profiles with slopes greater than the mean (positive weighting on E_1), 19.4% are without bars (h = 0.1 foot [3cm]). Of profiles with slopes less than the mean (negative weighting on E_1,) 18.6% are without bars (h = 0.1 foot [3 cm]). Using a height criterion (h) of 2.0 feet (60 cm), 47% of profiles without bars have slopes less than the mean and 53% have slopes greater than the mean. These data illustrate the lack of relationship between the presence or absence of bars and the slope of the profile in the inshore region.

We also found no relationship between the number of bars in a profile and the slope of the profile with the exception perhaps of those profiles with 4 or more bars. (Multiple bars are more frequently associated with slopes less than the mean [Fig. 19]). Examination of specific profiles with 4 or more bars and negative weightings on E_1 indicate that they are largely restricted to a portion of the Florida Keys (Profiles 395-407 and thus are believed to represent coral masses along the profile rather than bars.

FIGURE 17

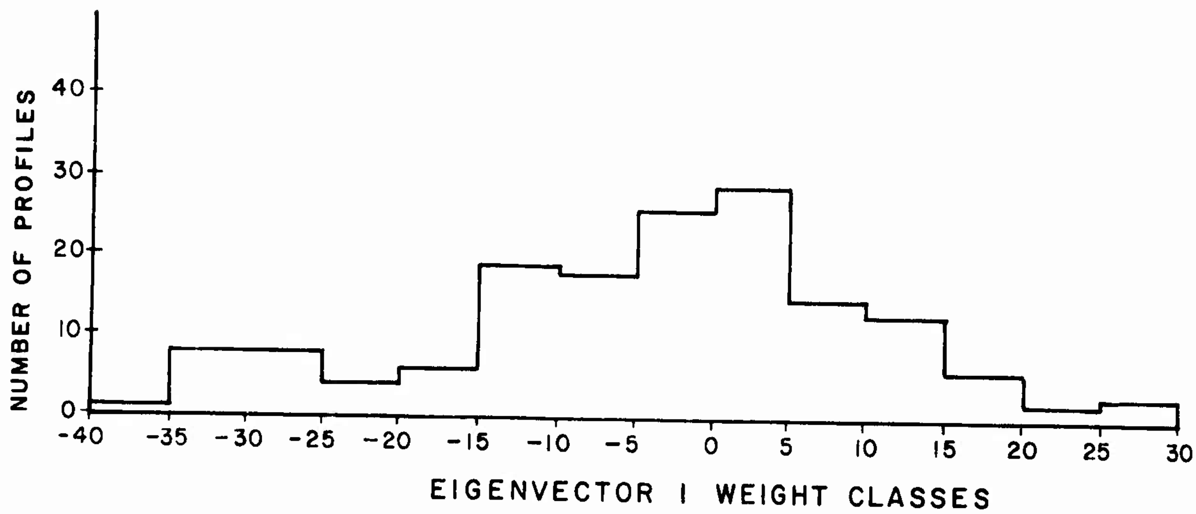
Plot of Profiles Without Bars



Plot of all profiles without bars ($h \geq 0.1$ ft [3 cm]) in Eigenvector 2,3 space.

FIGURE 18

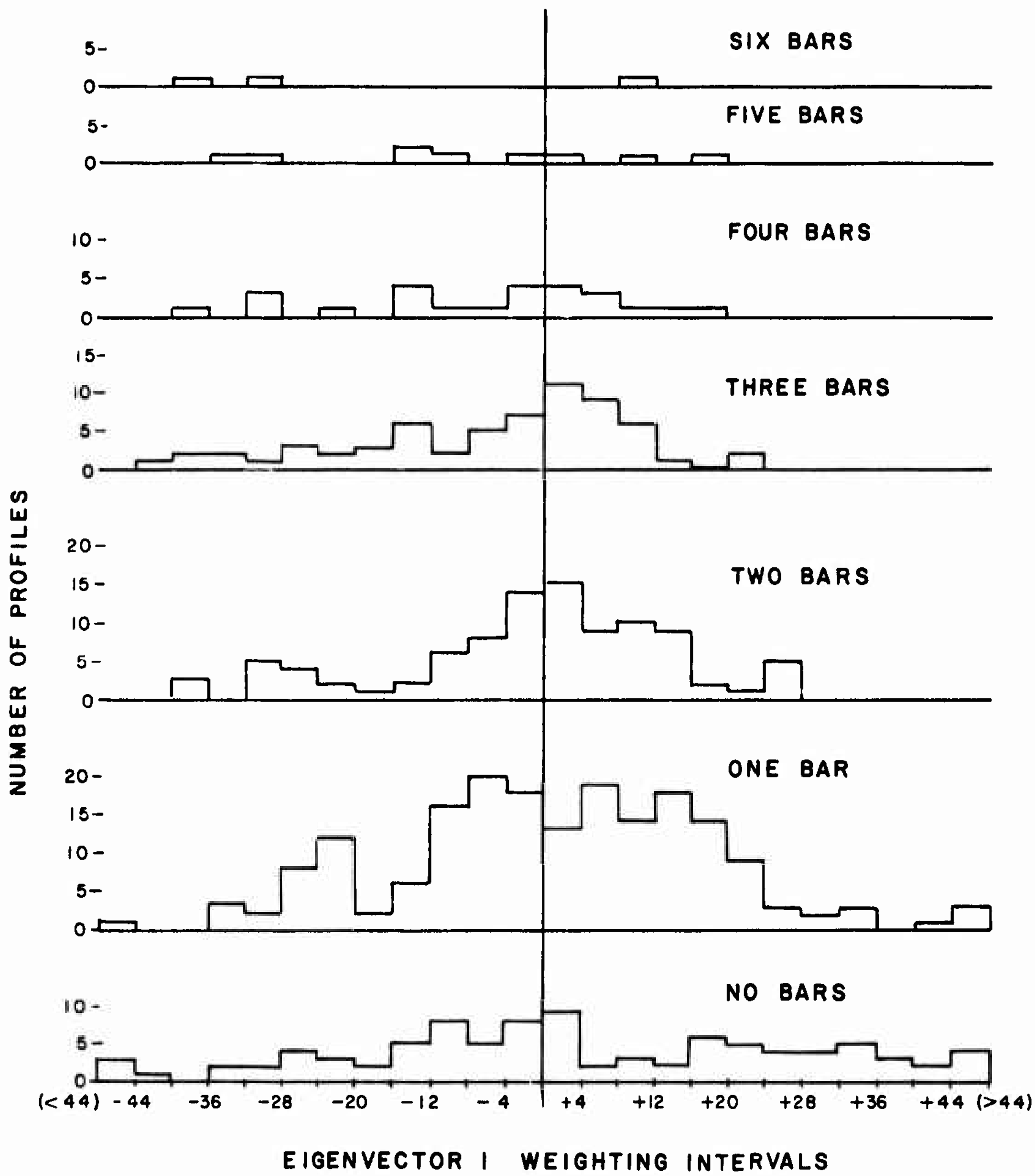
Profile Histogram ($h \geq 2.0$ ft [60 cm])



Histogram of profiles with 1 or more bars $h \geq 2.0$ ft [60 cm]) according weightings on E_1.

FIGURE 19

Profile histogram (h$\geq$0.1 ft [3 cm])



Histogram of bar frequency by Eigenvector 1 weight classes for profiles with 0, 1, 2, 3, 4, 5, and 6 bars (h$\geq$0.1 ft (3 cm]).

When separate analyses of the New Jersey coast were conducted, the first eigenvector was characterized by both a slope and curvature component (Fig. 4), indicating that within this region there is a partial correlation between slope and bars. We must conclude therefore that there is no consistent relationship, when extensive coastal areas are considered, between either the presence or the absence of bars or the presence of multiple bars and the degree of slopes in the inshore region.

Inshore Versus Offshore Bathymetry

We found no relationship between profile slope and the presence or absence or number of bars present within the first 1,200 feet (365 m) of the shoreline. However, this observation does not preclude the existence of a relationship between inshore bar-trough morphology and offshore slopes.

In an earlier program (Resio et al. 1974) we analyzed profiles taken from the shoreline to 9 miles (15 km) offshore using eigenvector analyses and found that 93% of the topographic variance in the offshore zone was accounted for by the first two eigenvectors. The first eigenvector characterized slope departures from the mean and the second, curvilinear departures from the mean. We selected 69 offshore profiles, matched them in location with 69 inshore profiles, and merged the two data sets which gave us 69 profiles of 46 depth variables each. A new set of eigenvectors were then calculated to assess the relationship between inshore and offshore bathymetry. The percentage of variance explained by each of the new eigenvectors was compared to that of the inshore profile set and that of the offshore profile set (Resio et al. 1974) (Table 2). In the inshore and the offshore eigenvector analyses, the first three eigenvectors account for more than 95% of the topographic variance in the original data. For the 69 matched profiles, the first 6 eigenvectors are needed to account for an equivalent percentage of the variance. Apparently, the topographic relationships between the inshore and offshore zones are more complex than within these zones.

The first two eigenvectors we calculated for the merged profile data set (Fig. 20) are similar in form to those we calculated for the offshore zone (Resio et al. 1974). The third and fourth eigenvectors of the merged data resemble the second and third ones calculated from the inshore profiles. Because each eigenvector calculated from a data set is mutually orthogonal, curvature departures from the inshore slope are uncorrelated with the slope variables of the offshore zone.

The form of the first eigenvector of the merged profile data set indicates a partial correlation between inshore and offshore slopes; that is when the offshore slope is steeper than the mean, the inshore slope is also steeper than the mean. In contrast, the second eigenvector (Fig. 20) indicates a partial correlation between slopes less than the mean inshore and slopes greater than the mean offshore and visa versa. Thus there are two modes of variation between inshore and offshore slopes, indicating a partial dependence and an independence of slope attributes between the two zones.

The third eigenvector of the merged profile data (Fig. 20) is similar in form to the second eigenvector of the inshore profiles (Fig. 7), indicating that this mode of inshore topographic variation is independent of offshore bathymetry as well as inshore slope.

TABLE 2

Comparison of percentage of variance explained at 95% level by eigenvectors of inshore, offshore, and merged inshore/offshore profiles.

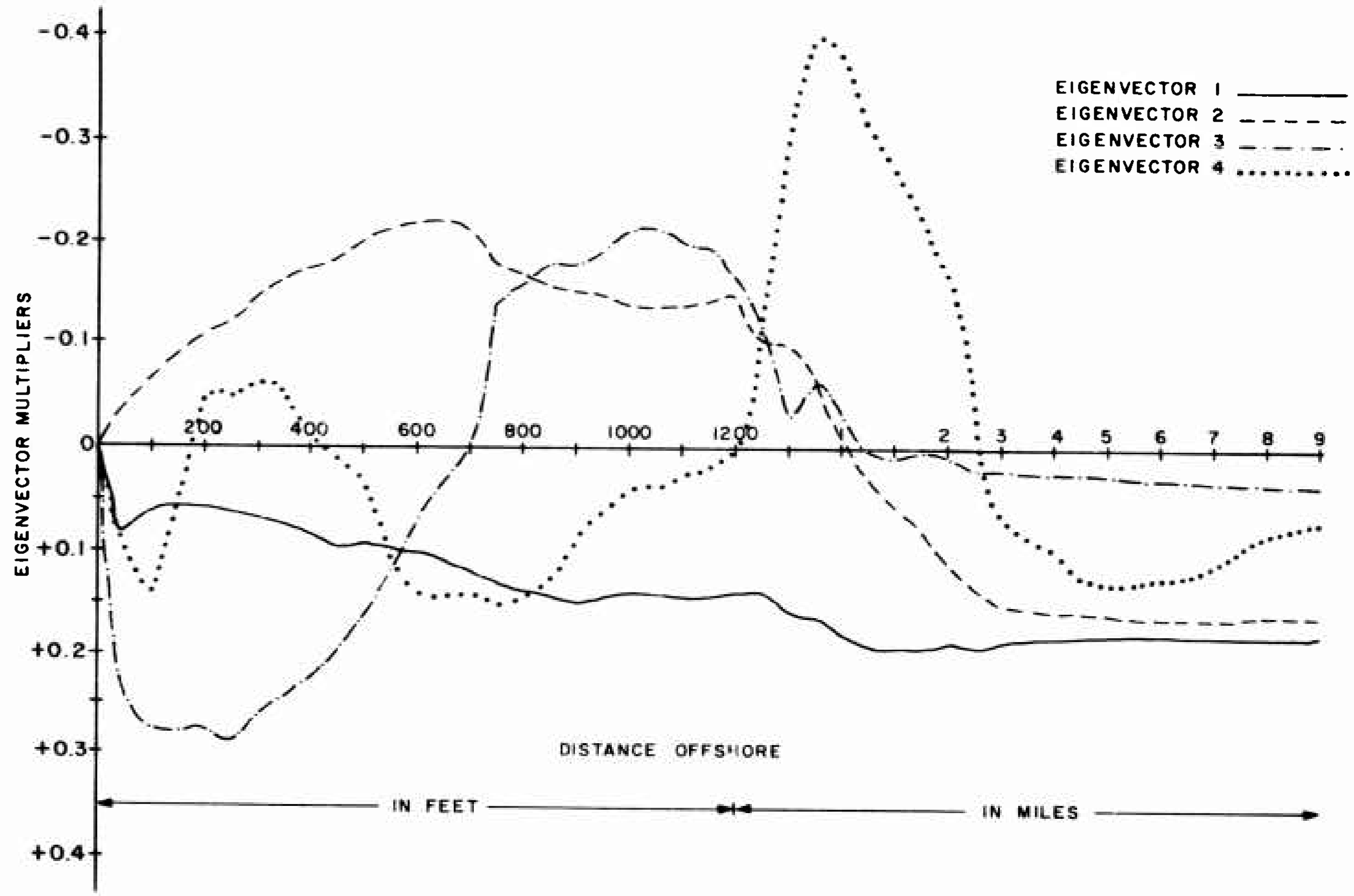
Cumulative Percentages of Variances

Eigenvectors	Inshore Profile	Offshore Profile*	Merged Profile
1	76.6%	72.9%	43.3%
2	91.9%	92.7%	69.9%
3	95.4%	96.4%	85.5%
4	____	____	90.1%
5	____	____	93.0%
6	____	____	94.9%

*From Resio et al. (1974)

FIGURE 20

Eigenvector Multipliers for First 4 Eigenvectors



Eigenvector multipliers by distance offshore for the first 4 eigenvectors calculated from 69 merged inshore-offshore profiles.

The fourth eigenvector of the merged profile data is similar in form to the third eigenvector of the inshore profiles but when weighted positively is correlated with a topographic maximum between .25 and 2 miles (.4 and 3 km) offshore. This topographic maximum suggests a shoal-like feature of the profile. When we crosschecked the profile locations which have large positive weightings on E_4 (merged) against the hydrographic charts from which the offshore data was collected, the shoals are indeed there. The form of the 4th eigenvector thus indicates that, when shoals are present seaward of the inshore zone, there can be a bar between 200 feet and 400 feet (60 and 120 m) from the shore. We found no other consistent relationship between inshore bar-trough morphology and offshore bathymetry.

The plotted multipliers of the merged-profile eigenvectors also indicate that the forms of the topographic variance change markedly at approximately 1,200 feet (365 m) offshore. Since we chose this distance to separate the inshore and offshore zones based upon theoretical bottom effects of approaching waves, the merit of this choice is in part substantiated.

Regionalization of Inshore Bathymetry

Since we are now able to effectively abstract inshore bar-trough morphology using the second and third eigenvectors of the basic data set (504 profiles), coastal reaches of the United States Atlantic and Gulf coasts may be classified accordingly (Fig. 21). Therefore we have defined four classes of inshore bathymetry according to the sign of the weightings on E_2 and E_3 (Table 3 below).

TABLE 3

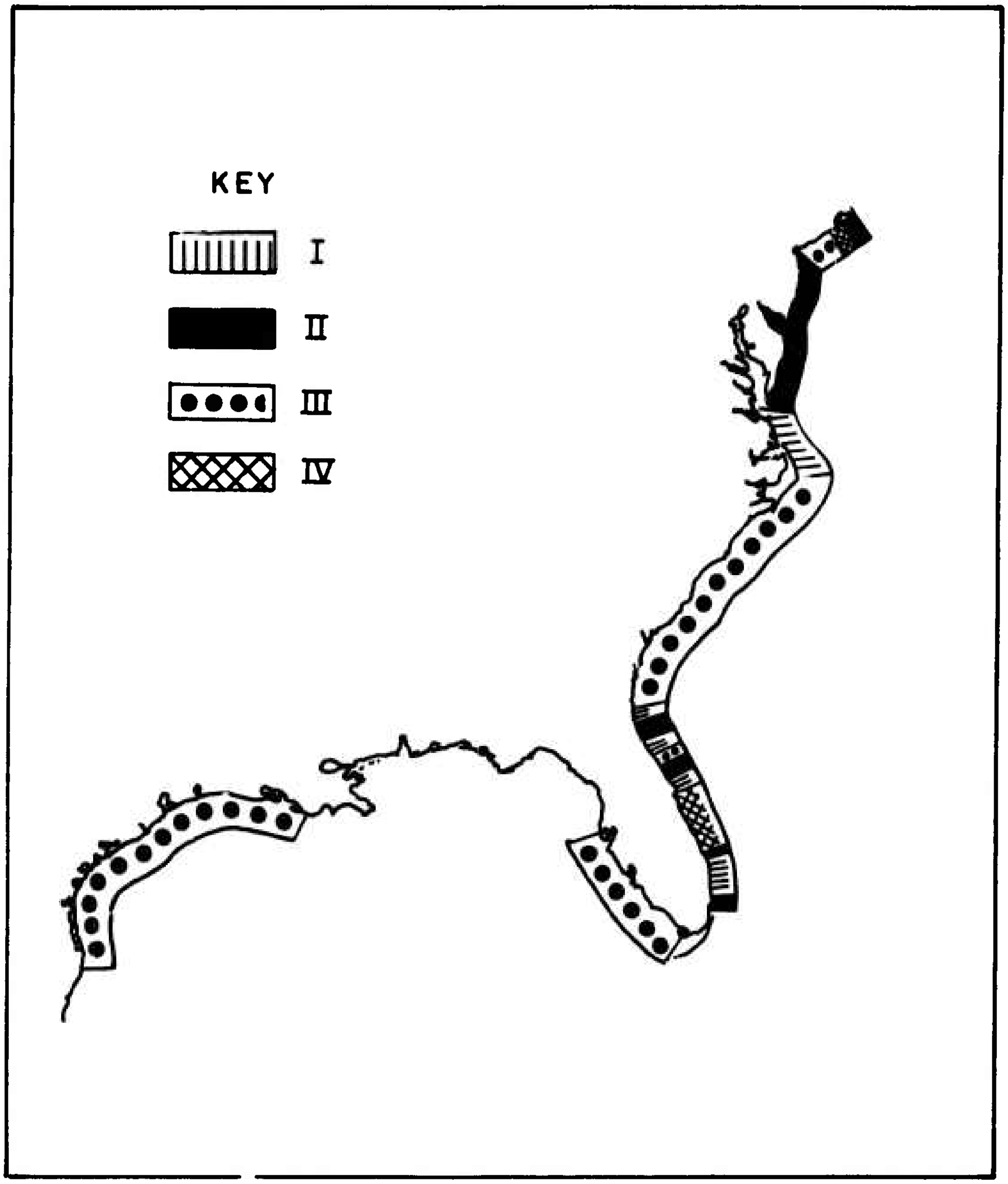
Definition of 4 Classes of Inshore Bathymetry

Class	Eigenvector 2	Eigenvector 3
I	+	+
II	+	-
III	-	-
IV	-	+

We constructed histograms of the frequency of bar occurrence (h=0.1 foot [3 cm]) by bar position along each of the 504 profiles and for the profiles within each of the four classes defined by the respective weightings on E_2 and E_3 (Fig. 13). The four classes effectively stratify profiles according to position, or positions, along the profile where bar occurrences are probable. Classes II and III are characterized by bars in the landward and seaward extremities of the profile. In Class III the seaward bar position dominates although the landward position dominates in Class II profiles. Classes I and IV are characterized by bars in the middle portion of the profile with a bar between 300 and 650 feet (90 and 200 m) for Class I and between 450 and 850 feet (135 and 260 m) for Class IV profiles.

FIGURE 21

Locations of Classes



Location map of $E_{2,3}$ classes (see Table 3).

The position, or positions, of bars in the profile seen in the histograms of bar frequency is consistent with the physical interpretations of the joint effects of E_2 and E_3 which we discussed earlier (Fig. 12). The relative weightings on these two eigenvectors provide a sound basis for classifying reaches of coast according to profile form. There are long reaches of homogeneous class composition (except for the Long Island coast and portions of the east coast of Florida) and there is a transition between homogeneous reaches where the shoreline trend changes: New York harbor, Chesapeake Bay, Cape Hatteras, the Georgia-Florida border, Cape Canaveral, and Miami. These change locations suggest that the orientation of the coast and the directional components of ongoing processes may be determining factors in inshore morphology. The absence of detailed and commensurate data on coastal processes for the study area preclude more detailed assessment of process-form relationships.

SUMMARY AND CONCLUSIONS

In this study we specify the characteristic forms of variation of the subaqueous beach-zone morphology and the organization of these variations along Atlantic and Gulf coasts of the United States. Principle component or eigenvector analyses are ideally suited to this task. Using these analyses the major independent modes of topographic variation from the mean are isolated as new, complex variables which can be used to measure the overall form of and local variation within inshore profiles. More than 97% of the topographic variance contained within the set of 504 profiles of the study area is explained by the first three eigenvectors calculated. Each of the three principle components we isolated has physical significance. The first eigenvector characterizes profile slope departures from the mean and explains 76.6% of the total variance within the basic data set (504 profiles). The second and third eigenvectors, accounting for 15.3 and 3.5% of the variance, respectively, characterize curvilinear departures from the mean profile. These two modes of curvilinear departures from the mean were independent, or uncorrelated, suggesting that different processes are responsible for their respective occurrences. Also the curvilinear topographic elements are independent of the slope characteristics (E_1) of the inshore zone.

The curvilinear departures from the mean reflect bar or bar-like features of the original profiles. The dimensions of the curvilinear departures from the mean in the eigenvector forms are larger than the dimensions of bars in the original profile data, represent statistical abstraction of bars in the sample, and must be interpreted as the probable distribution of bars in the profile.

There is no relationship between the presence or absence of bars or the number of bars in the profile and the slope attribute of the profile. This does not agree with the findings of earlier investigators, (Zenkovich 1967, Lau and Travis 1973). The size of the sample in our study, 504 profiles, and the geographic distribution, from Long Island to Texas, were sufficient to adequately establish such a relationship if it did exist. For one limited coastal reach, the New Jersey coast, there was a partial positive relationship between slope and bars suggesting that the earlier work had perhaps been limited by sample size. However, the work by Lau and Travis (1973) indicated that there is theoretical support for a process-form relationship between bar occurrences and slope and thus the question merits additional study.

We also conducted analyses of the relationship between inshore bar-trough morphology and offshore topography. Inshore profile slope is only partially correlated with offshore slope and there is a significant inverse relationship between inshore and offshore slope. However, no relationship was found between offshore slope and the presence or absence of bars inshore. The only relationship between offshore topography and inshore bars is between one of the inshore modes of curvilinear form variation and the occurrence of shoals .25 to 2 miles (.4 to 3 km) offshore.

Therefore inshore slopes are in part the result of those processes operative in the offshore and in part of those processes restricted largely to the inshore zone. Except where offshore shoals are present, the form of the bar-trough morphology of the inshore zone is independent of offshore topography.

Four general classes of inshore bar-trough morphology are defined using the joint weightings on the second and third eigenvectors of the inshore profile; each class characterizes specific coastal reaches. In each class, characteristic positions of the bar on the profile are evident. Under one set of conditions, a negative weighting on the second eigenvector and a positive weighting on the third eigenvector, 99% of the profiles have at least one bar.

The independence of the three modes of topographic variation in the inshore precludes simple analyses of process-form relationships. An adequate time series of inshore topography with commensurate data on inshore processes is required before the details of inshore process-form relationships can be established. Theoretical models which fail to incorporate the independent modes of profile variation may then fall short of a complete description of process-form relationships.

The third eigenvector, characterizing only 3.5% of the topographic variance, is essential for adequate characterization of profile form. This 3.5% variance may reflect such short-lived phenomena as hurricanes or extratropical storms which might have long-lived effects on inshore bathymetry. The results reported in this study should greatly improve the experimental design needed to answer the numerous questions about inshore sediment dynamics.

APPENDIX

Descriptions of Basic Data Set Profiles

Profile Number	State	Geographic Locations: First Profile	Geographic Locations: Last Profile	Month/Year	Zero Point
1-20	NY	Montauk Pt.	Westhampton	-/33	MLW*
21-22	NY	Moriches Inlet		-/55	MLW
23-29	NY	Moriches	Cherry Grove	-/33	MLW
30---	NY	Jones Beach		8/59	SLD
31-35	NY	Far Rockaway	Rockaway Beach	7/61	MLW
36-76	NJ	Sandy Hook	Island Beach	7/53	MLW
77---	NJ	Hereford Inlet		----	MLW
78---	NJ	Cape May		----	MLW
79-113	MD	Fenwick Light	Ocean City	-/65	MLW
114-116	MD	Ocean City Inlet		-/65	MLW
117-133	VA	53rd St. Virginia Bch.	Rudee Inlet	6/68 6/71	
134-145	NC	Styron Hills	Ocracoke Inlet	----	MSL
146-151	SC	Folly Beach		5/34	MLW
152-153	SC	Hunting Island Beach		-/62	MLW
154-159	GA	Tybee Is.		-/64	MLW
160-161	FL	Naussau Sound	Little Talbot Is.	11/63	MLW
162-163	FL	Mayport		2/67	
164-188	FL	Ponte Vedra	Matanzas Inlet	1/64	MLW
189-237	FL	Flagler Beach	Sebastian	1/65	MLW
238-246	FL	Hutchinson Island	Jupiter Is.	-/64	MLW
247-249	FL	St. Lucie Inlet		-/62	
250-271	FL	Jupiter Is.	Jupiter Inlet	-/64	MLW
272-332	FL	Lake Worth Inl.	Boca Raton Inl.	4/67	MLW
333-342	FL	Deerfield Beach		4/62	MLW
343-394	FL	Deerfield Beach	Golden Beach	-/61	MLW
395-404	FL	Key West		-/62	MLW
405-411	FL	Caxambas Pass	Doctor's Pass	8/60	MLW
412-418	FL	Wiggins Pass	Bonita Beach	-/73	
419---		Captiva Island		-/73	MLW
420---	FL	Siesta Key		10/67	MLW
421---	FL	Lido Key		12/72	MLW
422-424	FL	Big Sarasota Pass	Longboat Key	10/67	MLW
425---	FL	Manatee/Sarasota County Line		----	MLW
426-437	FL	Mullet Key		-/64	MLW
438-439	FL	Clearwater Beach		11/64	MLW
440-449	FL	St. Andrew Pt.	St. Andrew Sound	-/73	
450-453	TX	Sabine Pass		9/68	SLD
454-477	TX	Rollover Fish Pass		-/56	
478-485	TX	Galveston		7/68	SLD
486-489	TX	Freeport		8/68	SLD
490-493	TX	Matagorda		9/68	SLD
494-497	TX	Aransas Pass		8/68	SLD
498-500	TX	Port Mansfield		8/68	MSL
501-504	TX	Brazos Santiago		8/68	SLD

* MLW - Mean Low Water
SLD - Sea-Level Datum (U.S. Coast and Geodetic Survey)
MSL - Mean Sea Level

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